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Atlantic Shelf Sand Ridge Study: Physical Oceanography and Sediment Dynamics Data Report

by

Paul Dragos and David G. Aubrey

February 1990

Technical Report

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Woods Hole, Massachusetts 02543

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ABSTRACT

This report describes and presents the hydrodynamic measurements made during the Atlantic Shelf Sand Ridge Study at and near Peahala Ridge, offshore of Long Beach Island, New Jersey, in Spring 1985. The intent of this phase of the study was to examine the physical oceanographic and fluid mechanical processes in the vicinity of Peahala Ridge, one of the large shore-oblique sand ridges common in the area, and from this to identify those processes responsible for sand transport near the ridge with particular reference to its generation, maintenance and migration. The field measurement program was carried out from March to May 1985 by scientists and staff of the Woods Hole Oceanographic Institution. It included measurements of currents, temperature, waves, pressure and near-bed velocity profiles. This phase was part of a larger oil industry study that included extensive geological and geophysical measurements of Peahala Ridge and other ridge-and-swale areas of the mid-Atlantic continental shelf.

ACKNOWLEDGMENTS

The successful execution of the Peahala Ridge field program was made possible through the efforts of many individuals including: Dr. William D. Grant, Dr. A.J. Williams, III, Steve Boyd, Virginia Fry, Harry Jenter and Maggie Goud. For all their help the authors are most grateful. The authors would also like to express their appreciation for the professional work of Captain Wally Van Horn and the crew of the R/V *Atlantic Twin*, and for the help of fishing vessel Snoopy and the Triton Dive Shop.

The authors would also like to express their appreciation to Rocky Geyer and Rich Signell for their data processing routines and helpful comments, and to Betsy Pratt for drafting figures.

The Atlantic Shelf Sand Ridge Study was the conception of Dr. William D. Grant and would never have happened without him. He is sorely missed.

This study was supported by the Cities Services Oil and Gas Corporation under agreement as of April 25, 1985, and the Woods Hole Oceanographic Institution's Coastal Research Center.

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1. INTRODUCTION

Sand ridges of various spatial scales are common features on existing continental shelves throughout the world; they also have been identified in the geological record as reservoirs for hydrocarbons. Recent (decade of the 1980's) focus on modern sand ridges has been directed towards defining the morphology of these features, and determining the mechanisms controlling their formation and evolution.

A particularly well-studied system of shore-oblique linear sand ridges exists on the inner continental shelf of the storm-dominated North American Middle Atlantic Bight, (MAB; e.g., Swift *et al.,* 1973, 1978; Swift and Field, 1981). On bathymetric charts, this ridge-and-swale topography is much more apparent than the larger-scale morphology on which it is superimposed. The ridges have spacings of 2 to 4 km, lengths of a few tens of kilometers, and heights of several meters, in an ambient depth of 10 to 20 m. The ridges form an acute angle with the coast, open to the north, of some 20° to 30°. The ridges are typically composed of coarse sediment, although mud ribbons can occur in some of the ridge troughs. Several researchers have suggested that these ridges are longitudinal bedforms that have formed during the Holocene transgression in response to intermittent southerly storm currents (e.g., Swift and Field, 1981).

The geological characteristics of the shore-oblique sand ridges of the MAB are well documented, but the physical mechanisms responsible for their formation, maintenance and evolution are poorly understood. Early hypotheses were qualitative and did not have a firm fluid dynamical basis. A more recent comprehensive mathematical model (Figuerido *et al.,* 1981; Huthnance, 1982a,b) applies to tidally dominated shelves, and has been successful in explaining some of the features of linear sand ridges on the tidally dominated shelf off southeastern England. This model is not satisfactory for the MAB, although some of its features may be relevant, because there are fundamental differences, from the point of view of sediment transport, between tidally-dominated and storm-dominated continental shelves.

Early flow measurements near the MAB sand ridges (Palmer *et al.,* 1975; Swift *et al.,* 1977; Swift and Field, 1981) indicate peak flows that are generally alongshore to the south with a small offshore component, oblique to the ridge crests. Slightly more sophisticated measurements (Niederoda *et al.,* 1984) suggest that these flows are associated with downwelling. Calculations of sand transport based on these measurements indicate transport only during storms, and transport generally alongshore to the south and slightly offshore. These transport patterns are consistent with orientation of small-scale bedforms.

Similar sand ridges occur on the storm-dominated Middle Atlantic shelf of South America (Swift *et al.,* 1978; Parker *et al.,* 1982). Like the North American sand ridges, the South American ridges are oriented anti-cyclonically with respect to the dominant alongshore flow direction. This means that the crests are aligned roughly with the direction from which the most energetic forcing comes (northeast in the North Atlantic and southeast in the South Atlantic). Shore-oblique sand ridges also occur on the tidally dominated East Frisian shelf of the North Sea (Swift *et al.,* 1978); a particularly well studied set of sand ridges (the Norfolk Sandbanks) exists on the tidally dominated shelf off southeastern England (e.g., Caston and Stride, 1970; Caston, 1972; Huthnance, 1972, 1982a,b). The geometry of the Norfolk Sandbanks differs from that of the sand ridges of the Americas (ridge crests are within a few meters of the surface in ambient depths of 30 to 40 m, widths are roughly 2 km, and spacing is roughly 9 km). In addition, the Norfolk Sandbanks are oriented cyclonically with respect to the dominant flow direction, in contrast to the American sand ridges.

This report describes and presents the hydrodynamic measurements made during the Atlantic Shelf Sand Ridge Study at and near Peahala Ridge, offshore of Long Beach Island, New Jersey, in 1985 (Figure 1-1). The intent of the study was to examine the physical oceanographic and fluid mechanical processes in the vicinity of Peahala Ridge, one of the large shore-oblique sand ridges common in the area, and from these measurements to identify those processes responsible for sand transport near the ridge with particular reference to its generation, maintenance and migration. The study was designed by Drs. W.D. Grant and D.G. Aubrey, with instrumentation design and support by Dr. A.J. Williams, III (all three were co-Principal Investigators). This phase of a much larger overall study (e.g., Stubblefield *et al.,* 1983) was for acquisition and preliminary analysis of a data set, to be used for verification of ensuing numerical modeling of ridge generation, maintenance and migration processes. These modeling efforts will begin in July, 1990, by Drs. Aubrey and Trowbridge of WHOI, following a hiatus of several years. The present data report describes the quality and extent of the available data..

2. THE FIELD PROGRAM

The experiment was designed and instrumented both to quantify the dynamics of the synoptic wind, current, bottom pressure and wave conditions over the entire nearshore region, and to quantify the bottom stress tensor in the immediate vicinity of Peahala Ridge. To do this, two vector-averaging current meters (VACM) were deployed on moorings offshore of Peahala Ridge at two locations north and south (Figure 2-1). Benthic Acoustic Stress Sensor (BASS; Williams, 1985; Williams *et al.,* 1986) tripods were deployed on the crest and in the nearshore trough of Peahala ridge and another tripod instrumented with four electromagnetic current meters (EMCMs) was deployed north of the Ridge. Two directional wave gauges were deployed on or near the ridge, and four temperature-depth recorders (TDRs) were deployed just outside the surf zone along the length on Long Beach Island. Figure 2-1 indicates the location of the various instruments. Wind data were obtained from the National Oceanographic Data Center for weather buoys offshore Cape May and offshore Sandy Hook. Figure 2-2 shows the duration of data recovered from each

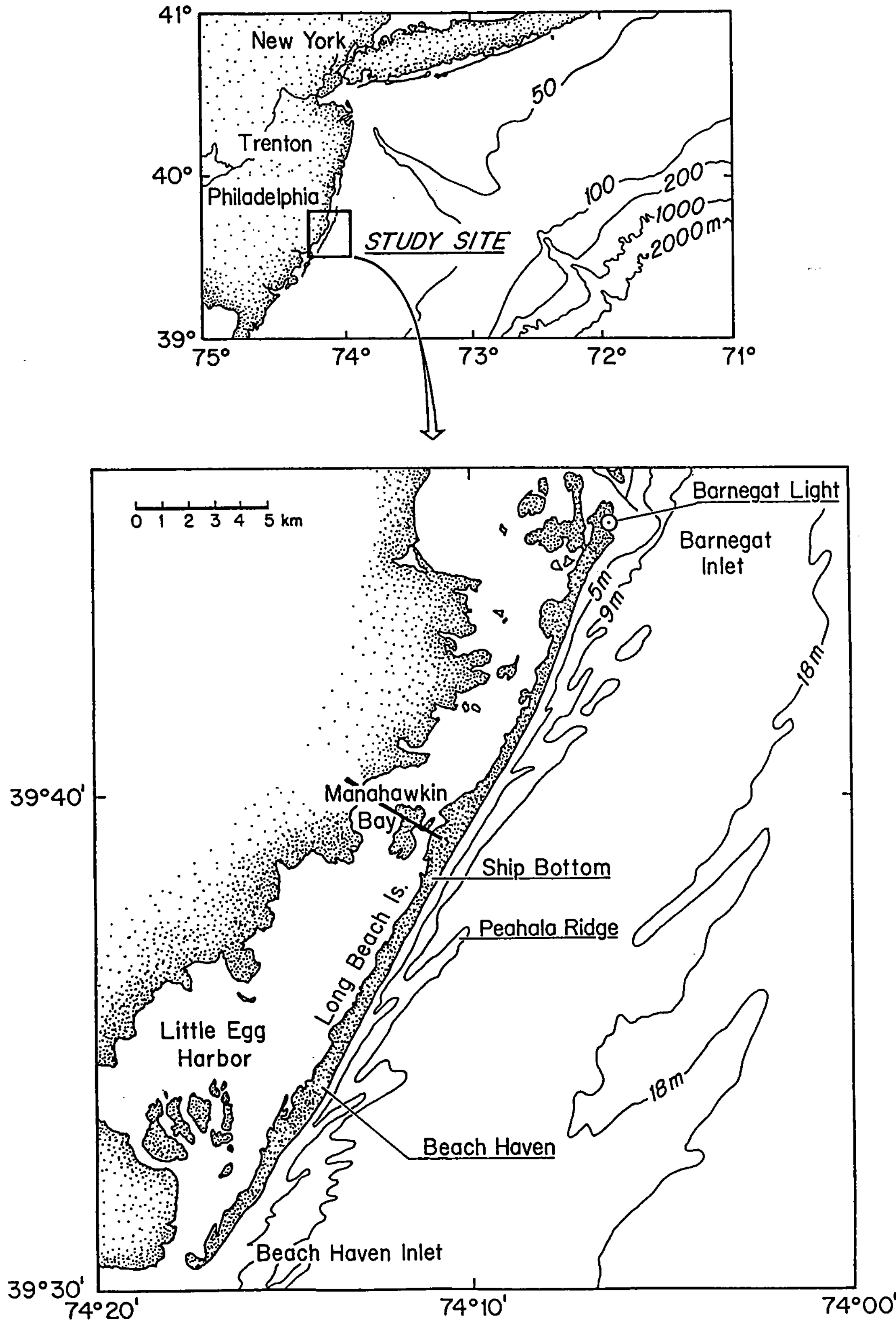

Figure 1.1: Long Beach Island, New Jersey, with specific location of Peahala Ridge.

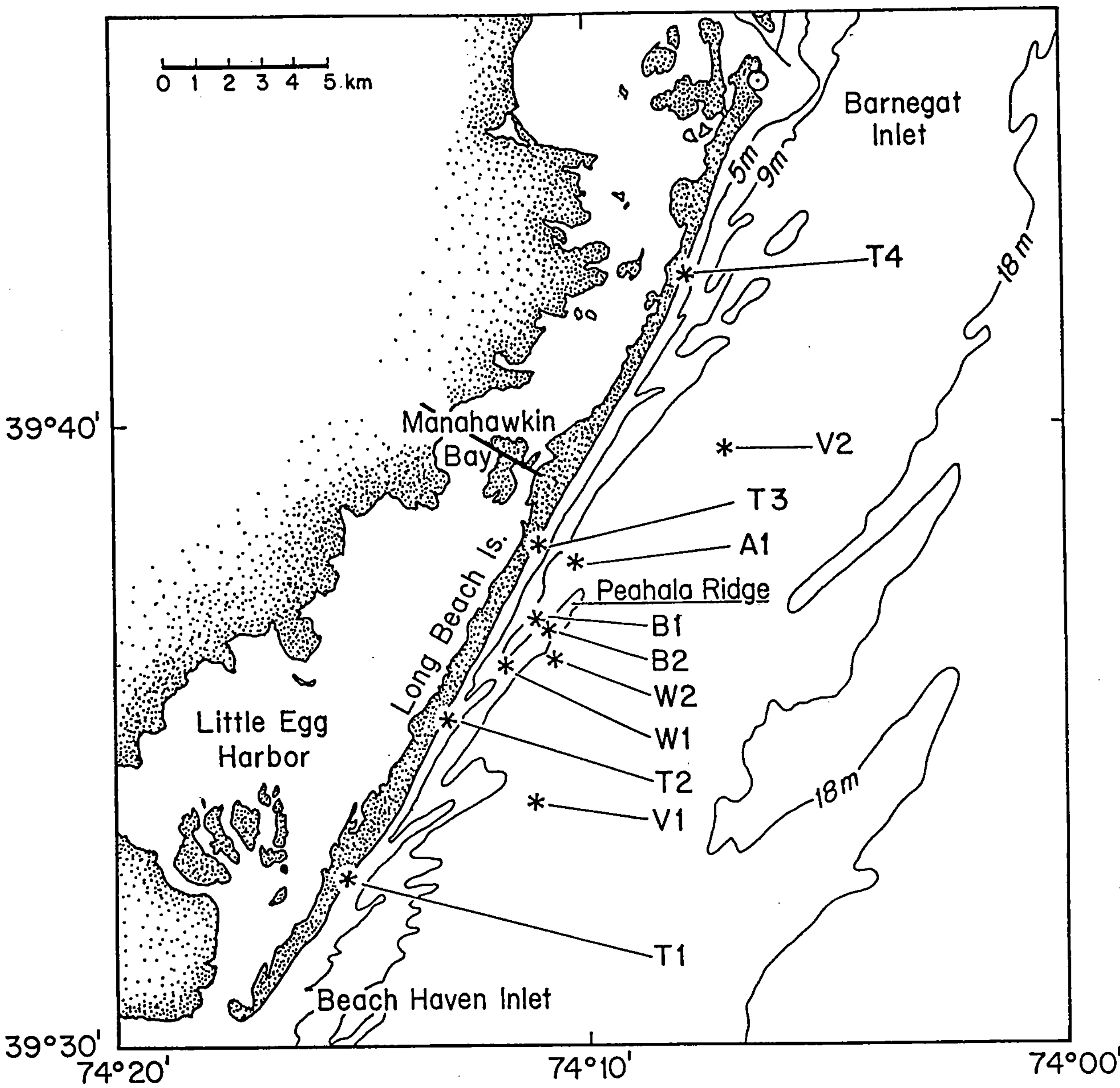

Figure 2.1: Instrument locations. (V: VACM, B: BASS Tripod, W: Wave Gauge, A: EM Current Meter Tripod, T: TDR).

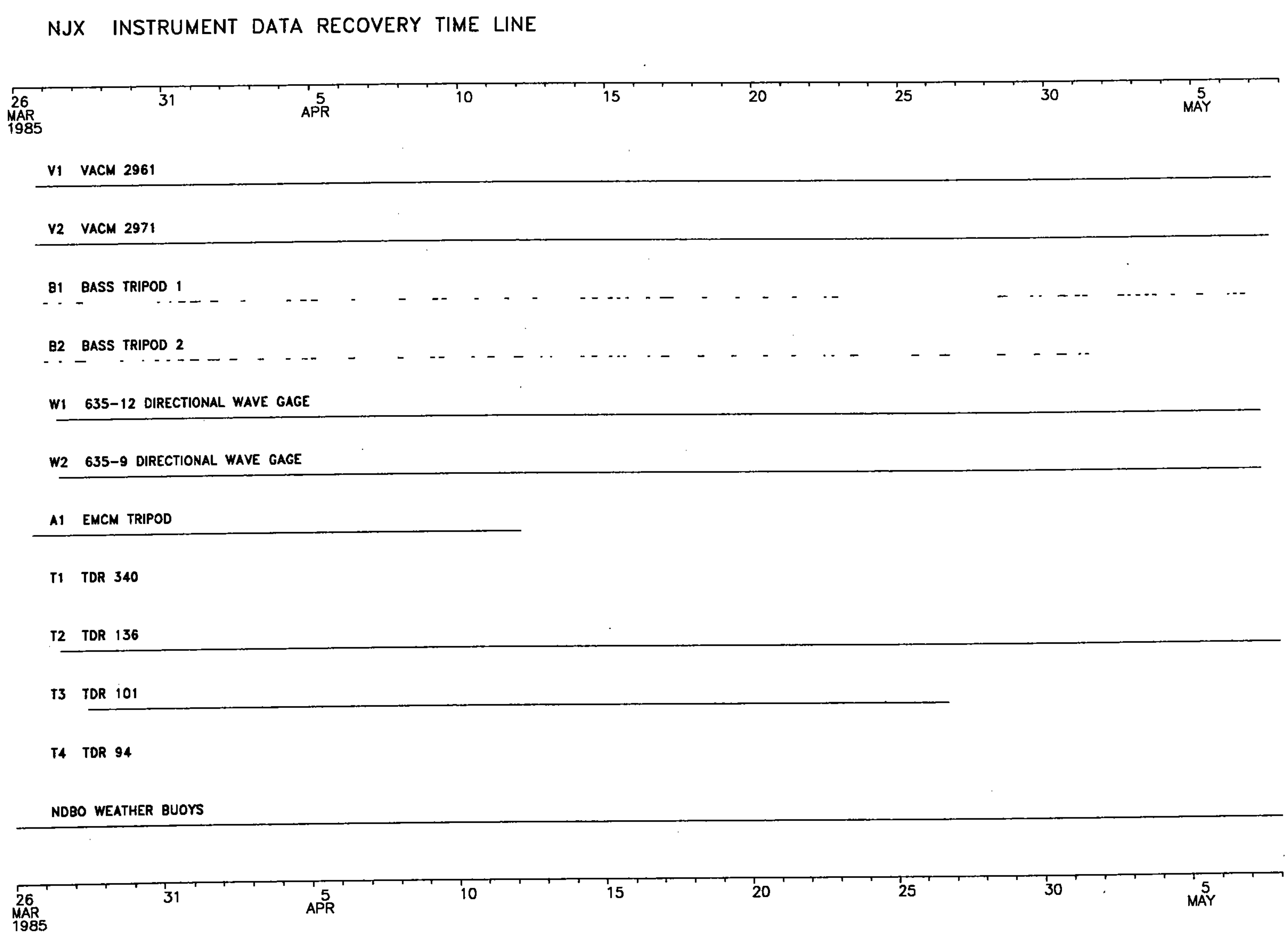

Figure 2.2: Instrument data recovery time line.

Table 2-1

Moored instrumentation.

Mooring Name Lat/Long Water Depth	Instruments	Sensors	Sensor Depth (m)	Sample Rate (min)	Start Date	# Days
V1: Offshore South 39°33.90'N 74°11.10'W 15 m	VACM 2961	u, v velocity	11.3	3.75	3/26/85	41
V2: Offshore North 39°39.60'N 74°07.70'W 14.9 m	VACM 2971	u, v velocity temperature	11.6	3.75	3/26/85	41
44009 Cape May 38°30.00'N 74°36.00'W 28 m	WEATHER BUOY	wind speed direction air temp sea temp baro pres	-	60	-	-
44012 Cape May 38°48.00'N 74°36.00'W 24 m	WEATHER BUOY	wind speed direction air temp sea temp baro pres	-	60	-	-
ALSN6 Sandy Hook 40°30.00'N 73°48.00'W 28 m	WEATHER BUOY	wind speed direction air temp sea temp baro pres	-	60	-	-

Table 2-2

Bottom tripod instrumentation.

Mooring Name Lat/Long Water Depth	Instruments	Sensors	Sensor Height (cm)	Sample Rate	Start Date	# Days
B1: 39°36.82'N 74°11.21'W 12 m	BASS BS4/B	u,v,w velocity	29,59, 119,230	5hz on command	3/26/85	36
	Sea Tech 35D,101	light transmission	87,176			
	Paro 13032	pressure	230			
		temperature	60,116, 230			
B2: 39°36.65'N 74°10.91'W 6 m	BASS BS3/E	u,v,w velocity	28,58, 118,228	5hz on command	3/26/85	41
	Sea Tech 36D,41D	light transmission	85,177			
	Paro 9129	pressure	228			
		temperature	59,118, 228			
W1: 39°36.01'N 74°11.89'W 7 m	DWG 635-12 s/n 23	u,v velocity	205	3.75min avg & 17min burst @1hz every 3 hrs	3/26/85	42
		pressure, temperature	50			
W2: 39°36.19'N 74°10.75'W 15 m	DWG 635-9	u,v velocity	215	17min burst @1hz every 4 hrs	3/26/85	42
		pressure	80			
A1: 39°37.68'N 74°10.30'W 12 m	EM current meters	u,v velocity	37,60, 117,236 332	17min burst @1hz every 3 hrs	3/26/85	14

Table 2-3

Bottom mounted instrumentation.

Mooring Name Lat/Long Water Depth	Instruments	Sensors	Sensor Height (cm)	Sample Rate	Start Date	# Days	Elev. (m)
T1: 39°33.10'N 74°14.50'W 3 m	TDR 340	pressure temperature	50	15 min	3/26/85	0	-4.39
T2: 39°35.20'N 74°13.00'W 3 m	TDR 136	pressure temperature	100	15 min	3/26/85	42	-1.62
T3: 39°37.80'N 74°11.20'W 4 m	TDR 101	pressure temperature	75	15 min	3/27/85	29	-5.39
T4: 39°42.20'N 74°07.75'W 6 m	TDR 94	pressure temperature	50	15 min	3/27/85	0	-5.33

instrument. In addition, a side scan sonar survey of the Ridge and vicinity was performed and, where divers were used to aid in deployment, bottom grab sediment samples were taken. Tables 2-1 through 2-3 provide a summary of the instrumentation.

Current Measurement

To quantify the synoptic currents, two Vector Averaging Current Meters (VACMs) were deployed on chain moorings at sites approximately 3 km offshore and 6 km north (V2) and south (V1) of Peahala Ridge. They recorded average currents vectors every 3.75 minutes. The northern VACM also recorded temperature. The accuracy of the current measurement is estimated at several cm/s. Both VACMs were deployed on taut line moorings with the current sensor approximately 4 m above the bottom in 15 m of water. Both instruments had a 100% data return.

Near-Bed Velocity Profiles

In a homogeneous boundary shear flow with neutral stratification, the slope of the logarithmic velocity profile is an estimate of the boundary shear stress ρu_*^2. To measure stress in this way, three bottom tripods were each equipped with a vertical array of current sensors. Two used arrays of BASS current meters (described below) and the other used an array of EM current meters. One BASS tripod was deployed on the crest of Peahala Ridge, the other in the trough shoreward, while the EMCM tripod was deployed north of the ridge.

The BASS (Benthic Acoustic Stress Sensor) was developed at Woods Hole by Dr. A.J. Williams (1985) to measure turbulence in the oceanic bottom boundary layer. It measures instantaneous velocity from acoustic pulse travel times along four axes across a 15 cm measurement volume. In this experiment, four BASS sensors were arrayed vertically on each of two BASS tripods. The BASS tripods were also instrumented with two transmissometers, two thermistors, pitch, roll and compass sensors (see Table 2-2 for instrument heights). BASS was originally designed as a short-deployment, high-precision turbulence-measuring sensor with a velocity accuracy of ±0.03 cm/s. Configured in this way, and sampling at 5 hz, each BASS tripod generated a large volume of data and was impractical as a mean current measuring device. Instead a surface radio buoy was tethered to the tripod and supplied a telemetry link to shore. The BASS tripods sampled on command from a shore station during periods of high winds. Both tripods transmitted data without problem until May 2 when the B2 radio buoy was ripped away from its anchor in strong NE winds and waves.

The EM current meter tripod (A1) was instrumented with five EM current meters and recorded 17 min bursts at 1 hz rate every 3 hours. There were no supplementary measurements on this tripod. Unfortunately, only two channels of current worked properly during the experiment, and these only for 14 days.

Wave Measurement

Two Sea Data Corporation directional wave gauges were mounted on small bottom tripods and deployed in the study area. The 635-12 Wave, Tide and Current Recorder was deployed in 7 m of water on Peahala Ridge, while the 635-9 Wave Recorder was deployed adjacent to the Ridge on the offshore side in 15 m of water (Figure 2-1). Each wave gauge consisted of a 2-axis Marsh McBirney electromagnetic flow sensor, a Paroscientific quartz pressure sensor and temperature probe. These sensors provide ±10-15% velocity accuracy, 0.4 cm depth accuracy, and ±0.1° temperature accuracy. Both instruments were calibrated for velocity at Woods Hole before deployment and recorded internally to cassette tape. The 635-12 and 635-9 were programmed to record 17 min bursts of 1 hz velocity and pressure measurements every 3 and 4 hours, respectively. The 635-12 was also programmed to record continuously 3.75 min averages of velocity, pressure and temperature. The high frequency, 2-axis velocity and pressure data recorded in bursts were used to calculated wave statistics including height, direction and energy; the averaged data provide another time series of mean currents, tide and temperature. Neither instrument was equipped with pitch and roll sensors, and so had to be diver deployed and the EM current meter leveled. Both instruments had a 100% data return.

Tide Measurements

Four temperature-depth recorders (TDRs) were deployed on jetted pilings near the surf zone at four stations along the length of Long Beach Island (Figure 2-1). The elevation of each DTR was surveyed from shore after deployment during calm weather, so that absolute pressure differences could be calculated. These elevations are given in Table 2-3 relative to the 1929 Sea Level Datum (NGVD). Each uses a thermistor with an accuracy of ±0.15° and a strain gauge pressure sensor. All pressure sensors were calibrated at Woods Hole before deployment. All recorded internally to micro-wafer and were programmed to record every 15 min (averaging over one-minute samples). The instruments were deployed on 2-inch diameter pipes that had been jetted into the sediment by divers using a water pump. Unfortunately only two of the TDRs returned data; one for the duration of the experiment and the other for 29 days. The probable cause of the failures was the pounding the instruments received under breaking waves during times of high wave energy.

3. OBSERVATIONS

The measurements made during the 41 day deployment period are presented below. Most of the data are presented in a reduced form and some analysis has been performed to determine data quality and to draw some preliminary conclusions about the physical oceanography of the study area. All time are EST.

3.1 WIND AND CURRENTS

Data Reduction

The three sources of current observations during the study were the two VACMs (V1 and V2) and the 635-12 wave gauge current record. All three instruments recorded average horizontal current vectors every 3-3/4 minutes. The time series were first rotated into a north-south reference, and then averaged to 1-hour intervals using a running mean filter centered on the hour. Low-frequency time series were also calculated using a 33 hour low-pass filter (half-amplitude at 33 hours). The hourly average wind velocity was likewise low-pass filtered. Harmonic analysis was performed on the hourly current time series to determine their tidal constituents. Mean up-coast (northerly) and down-coast (southerly) currents, and the major and minor axes of low frequency wind and currents were calculated. Finally, complex correlations were calculated between the wind and current low-pass time series to determine the effect of the wind forcing.

Tidal Currents

A summary of the M_2 tidal ellipse statistics is shown in Table 3-1 and plotted in Figure 3-1 for the three current time series. The time series are shown in Figures 3-2 through 3-4 and the complete tidal harmonic analyses are shown in Tables 3-2 through 3-4. In addition, tidal harmonic analyses for the pressure time series from the 635-12 Wave Gauge W1 and the two TDRs are shown in Tables 3-5 through 3-7. The tidal component of the currents is small as expected in shallow water, only 2.5 cm/s out of as much as 40 cm/s. The ellipses for stations V1 and W1 show coast-normal orientation but at V2 the ellipse is oriented nearly north-south. The magnitude of the M_2 harmonic currents is listed in Table 3-1.

Wind Forcing

Low-frequency currents were calculated by low-pass filtering the data with a 33-hour filter (PL-33). Summaries of low-frequency motions are shown in Figure 3-5 as plots of major and minor axes of low-frequency variations at each station and for the wind. Vector plots of the low-pass wind and currents are shown in Figure 3-6. Shown in Figures 3-7 through 3-12 are low-pass currents for stations V1, V2, W1, A1, B1 and B2. The currents for the BASS tripods are sporadic given the nature of the sampling scheme. Low-pass winds and hourly temperature and pressure for the three Weather Service Buoys are shown in Figures 3-13 through 3-18. Wind roses are shown as Figures 3-19 to 3-21.

The low-frequency currents constitute by far the largest part of the current signal with peaks as high as 30 cm/s. They are well correlated with the wind, as seen in Table 3-8. The angle between the wind and current is substantially different for the north and south Weather Buoys (44009 and ALSN6). This may be due to the turning of the wind field between the two stations. The low-frequency currents at station W1 (on Peahala Ridge) show a slight counterclockwise turning from those measured by the VACMs farther offshore. This may be due to topographic steering. One might expect more turning of the low-frequency flow at B1 since it is in the shoreward trough of Peahala Ridge, but this does not seem to be true (Figure 3-11). Mean currents in the up- and down-coast directions (Figure 3-22) were between 2 and 4 cm/s, approximately balanced and generally oriented along-coast with the up-coast component turned slightly onshore.

Table 3-1

Summary of harmonic tidal analysis, M_2 (semi-diurnal) component. Shown are major and minor axes in cm/sec, bearing from true north and phase relative to Greenwich.

M_2 Tidal Components				
	Major	**Minor**	**bearing**	**phase**
V1: VACM South	2.62	0.78	312°	258°
V2: VACM North	2.76	0.53	7°	267°
W1: Wave Gauge	1.13	0.46	312°	232°

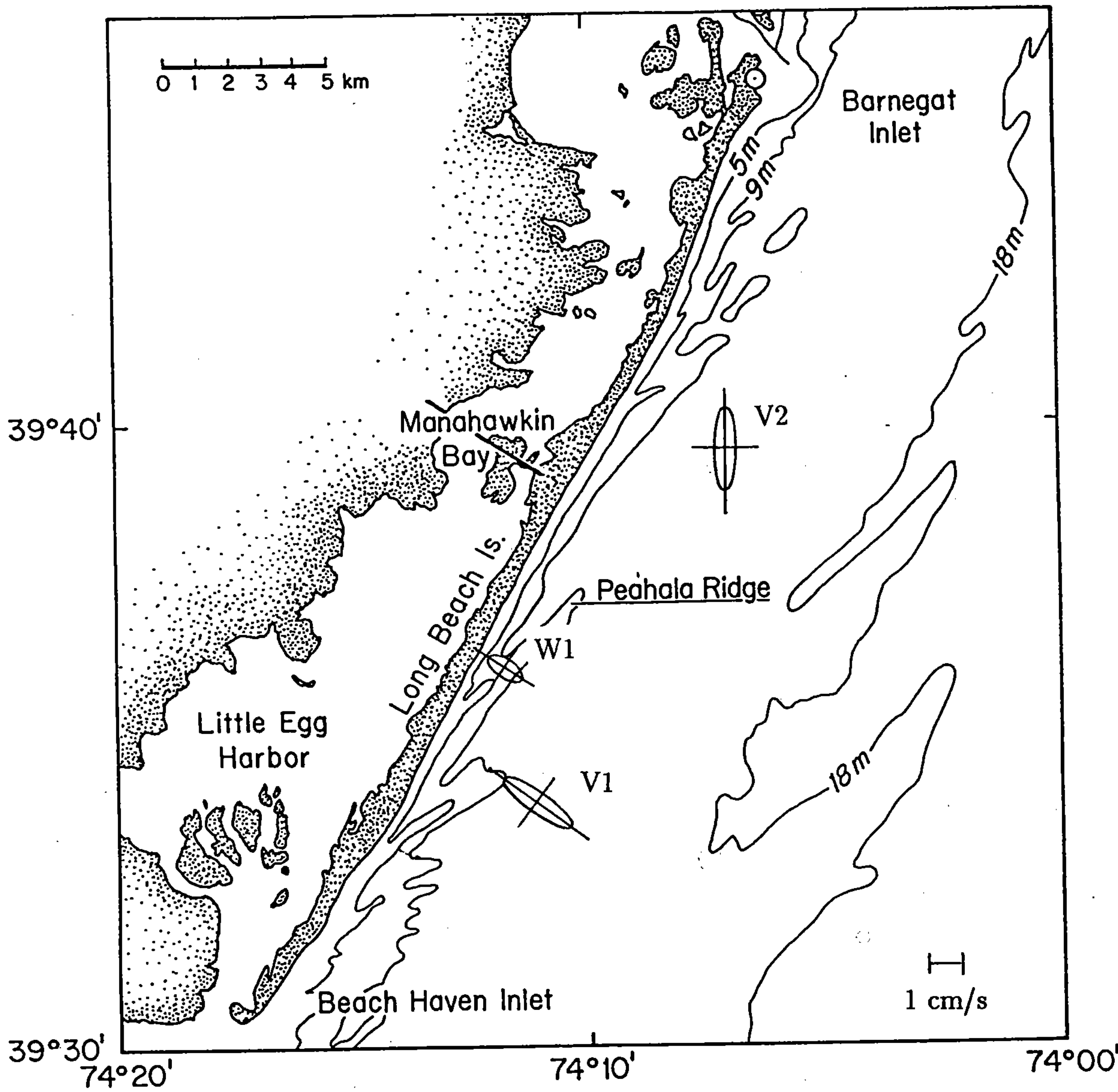

Figure 3.1: M_2 tidal ellipses for VACM V1, VACM V2 and Wave Gauge W1. For clarity the ellipses are not drawn to scale with the actual tidal excursion amplitude during a tidal cycle.

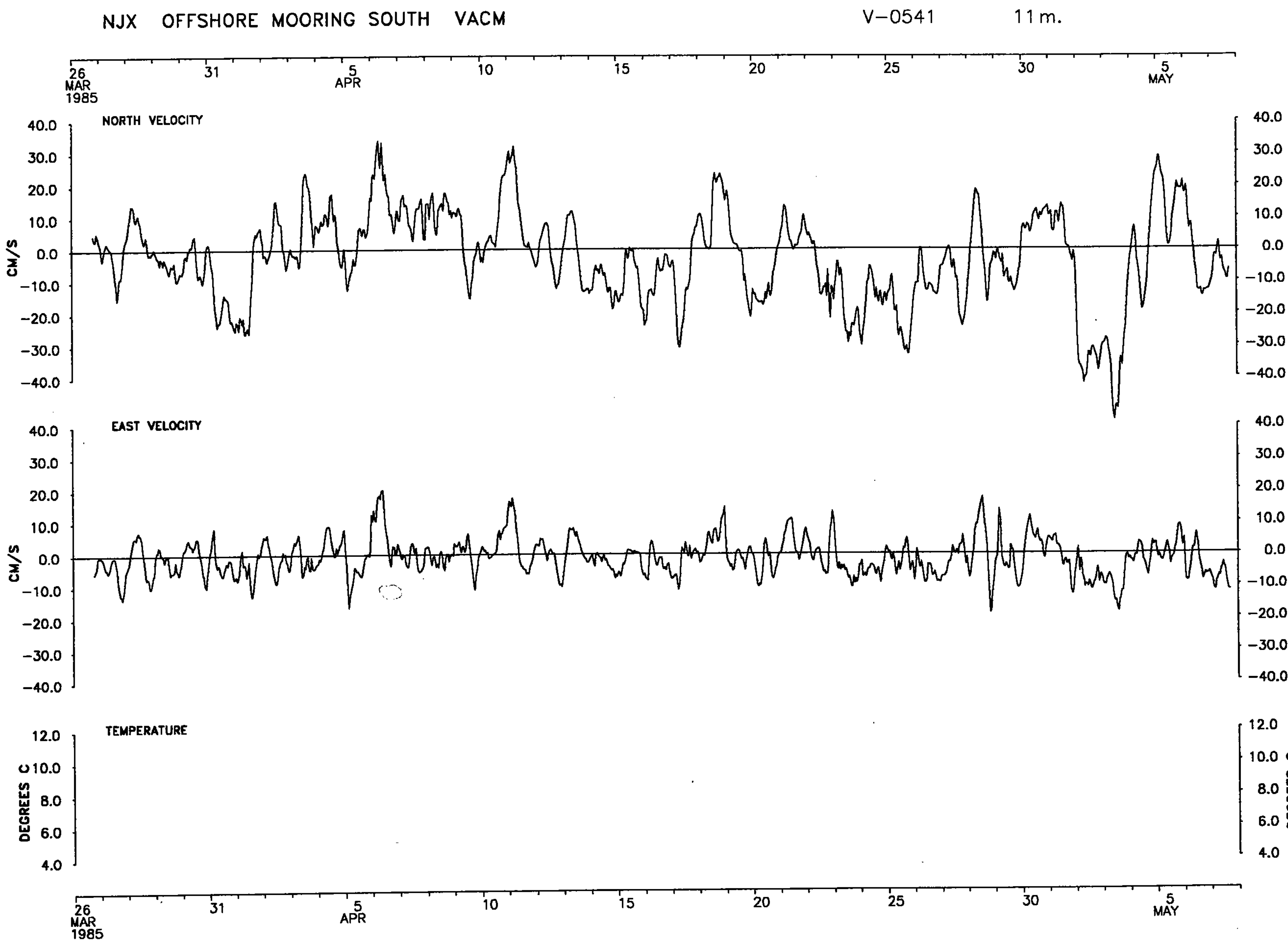

Figure 3.2: Hourly time series of current at 11 meters depth from station VACM V1. Note temperature was not recorded at this station.

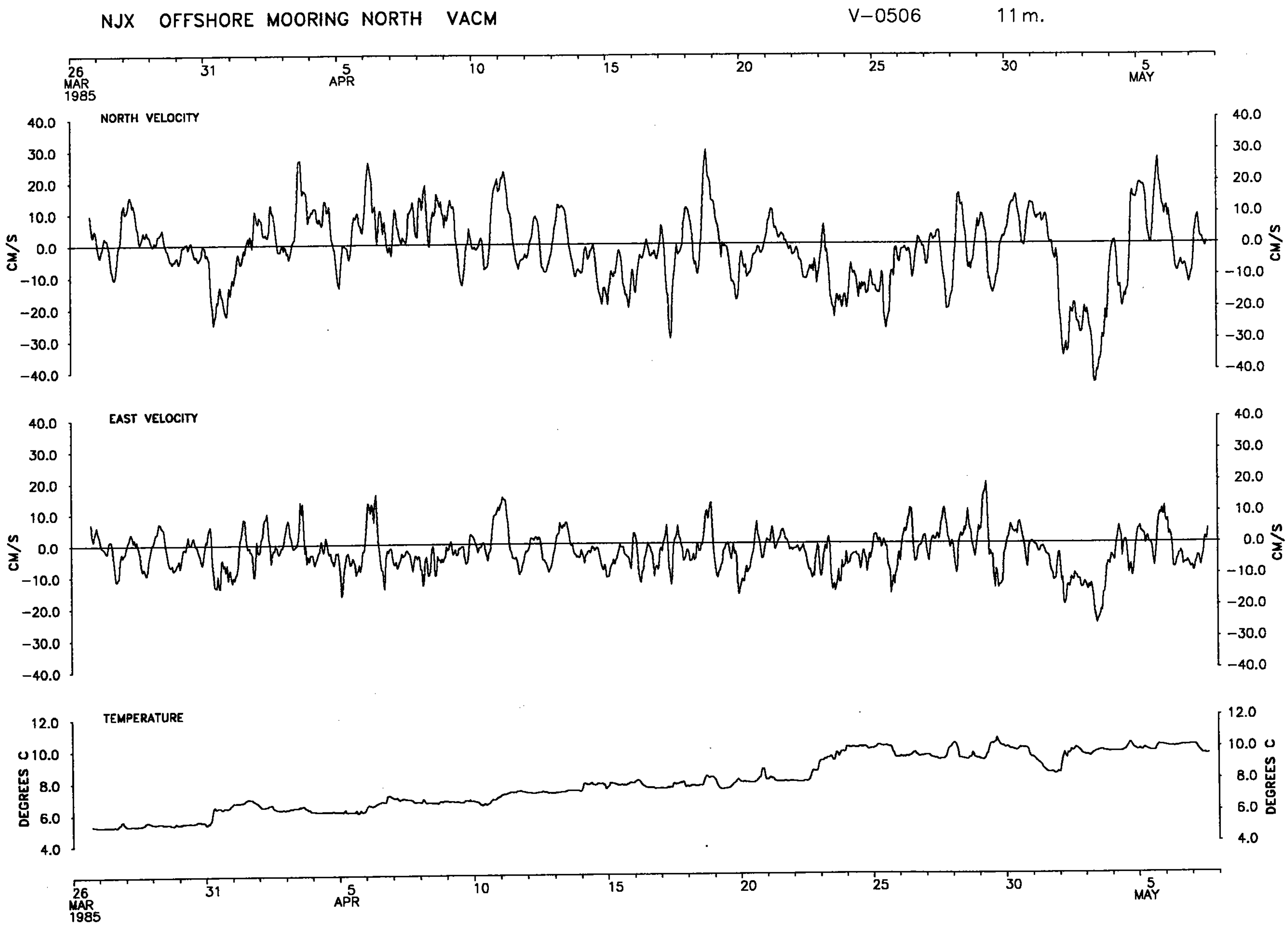

Figure 3.3: Hourly time series of current and temperature at 11 meters depth from station VACM V2.

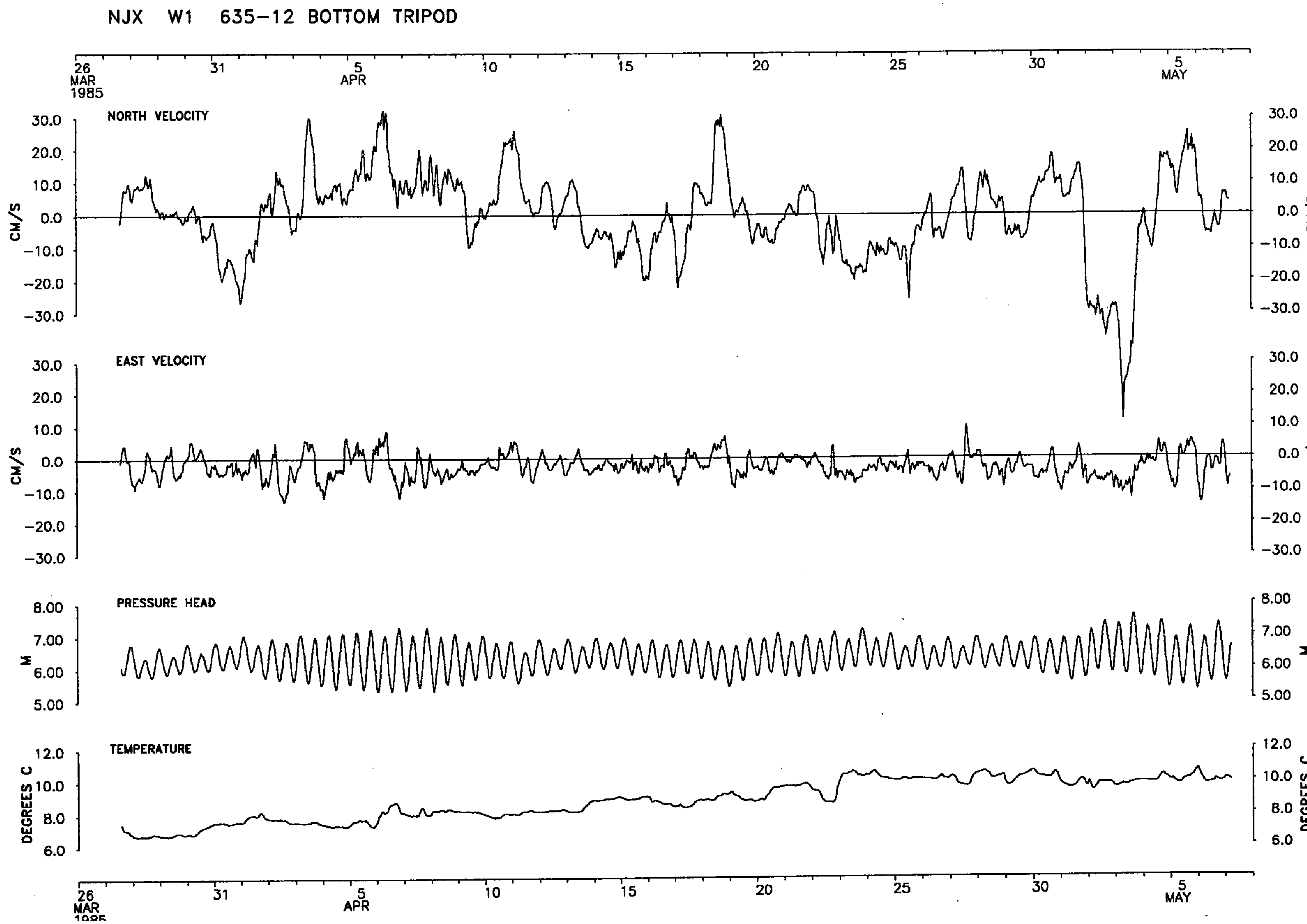

Figure 3.4: Hourly time series of current, temperature and pressure at 7 meters depth from station Wave Gauge W1.

FINAL ANALYSIS RESULTS IN CURRENT ELLIPSE FORM

FOR STATION 2961-, OFFSHORE MOORING SOUTH,LOCATED AT 39 33.90, -74 11.10
OVER THE PERIOD OF 850327, 0 TO 850507,220000

NODAL MODULATION AND INFERENCE CORRECTIONS HAVE BEEN MADE
AMPLITUDES HAVE BEEN SCALED TO COMPENSATE FOR THE PRIOR APPLICATION OF MOVING AVERAGE FILTERS
PHASES ARE GREENWICH

	NAME	FREQ (CPH)	MAJOR	ERR	MINOR	ERR	INC	ERR	PHASE	ERR	
1	Z0	0.00000000	2.958	0.494	0.000	0.268	69.0	5.4	180.0	9.1	
2	MM	0.00151215	5.099	3.996	-0.543	1.275	83.3	14.9	49.5	46.9	
3	MSF	0.00282193	3.416	4.019	-0.086	1.187	84.7	20.3	82.1	66.4	
4	ALP1	0.03439657	1.280	0.627	-0.117	0.315	75.3	14.4	308.8	28.4	
5	2Q1	0.03570635	1.997	1.016	-0.237	0.663	73.7	19.7	19.4	29.6	
6	Q1	0.03721850	1.185	0.936	0.905	0.769	57.1	122.0	152.7	128.5	
7	O1	0.03873065	4.199	1.006	0.741	0.669	72.2	9.7	282.7	14.3	
8	NO1	0.04026860	0.593	0.649	0.116	0.636	46.3	65.2	259.2	66.5	
9	P1	0.04155259	1.115	0.878	-0.287	0.716	57.6	22.3	294.6	26.7	INF FR K1
10	K1	0.04178075	3.369	0.804	-0.868	0.657	57.6	22.3	294.6	26.7	
11	J1	0.04329290	0.860	0.934	0.440	0.835	51.6	86.8	258.5	92.4	
12	OO1	0.04483084	0.217	0.559	0.079	0.594	41.2	192.3	340.1	182.8	
13	UPS1	0.04634299	0.847	0.709	0.402	0.463	106.2	50.0	337.7	64.8	
14	EPS2	0.07617731	0.278	0.346	-0.030	0.366	75.6	76.9	346.0	72.6	
15	MU2	0.07768947	0.646	0.355	-0.034	0.363	124.6	32.4	225.2	31.6	
16	N2	0.07899925	0.538	0.370	0.226	0.346	0.3	49.0	30.9	51.3	
17	M2	0.08051140	2.616	0.361	-0.776	0.359	137.7	9.0	258.3	9.0	
18	L2	0.08202355	0.919	0.491	-0.013	0.474	28.5	29.5	105.2	30.6	
19	S2	0.08333334	0.494	0.438	-0.073	0.426	147.3	26.0	330.5	26.6	
20	K2	0.08356149	0.134	0.362	-0.020	0.352	147.3	26.0	330.5	26.6	INF FR S2
21	ETA2	0.08507364	0.362	0.267	-0.251	0.265	136.5	99.1	156.0	99.2	
22	MO3	0.11924206	0.342	0.176	-0.135	0.167	93.6	35.8	91.0	37.2	
23	M3	0.12076710	0.419	0.201	-0.091	0.200	46.0	29.4	265.0	29.5	
24	MK3	0.12229215	0.088	0.183	-0.014	0.175	76.1	117.5	46.4	122.8	
25	SK3	0.12511408	0.244	0.173	-0.027	0.169	59.3	40.3	265.2	41.4	
26	MN4	0.15951064	0.291	0.175	-0.082	0.169	66.3	37.5	79.7	38.6	
27	M4	0.16102280	0.271	0.177	-0.223	0.171	63.8	147.3	130.1	148.2	
28	SN4	0.16233258	0.355	0.172	-0.091	0.170	50.3	30.4	319.8	30.6	
29	MS4	0.16384473	0.357	0.171	-0.108	0.164	73.7	30.3	73.2	31.5	
30	S4	0.16666667	0.474	0.164	0.134	0.156	74.7	21.4	343.9	22.3	
31	2MK5	0.20280355	0.177	0.146	0.080	0.115	101.9	54.0	169.5	63.0	
32	2SK5	0.20844741	0.262	0.119	-0.182	0.131	33.4	65.4	110.8	63.1	
33	2MN6	0.24002205	0.466	0.136	0.129	0.096	77.4	13.8	244.6	18.5	
34	M6	0.24153420	0.272	0.132	0.138	0.102	66.6	34.6	229.2	40.2	
35	2MS6	0.24435614	0.285	0.126	-0.084	0.098	66.4	23.1	285.4	28.6	
36	2SM6	0.24717806	0.024	0.126	-0.012	0.092	72.8	351.1	287.1	62.7	
37	3MK7	0.28331494	0.137	0.102	-0.001	0.098	117.2	41.1	68.6	42.8	
38	M8	0.32204559	0.308	0.105	0.024	0.107	64.3	20.1	201.4	19.8	

NO. PTS= 1007 NO. VALID X,Y PTS= 1007 1007

ORIGINAL DT =0.062500 HOURS DATA FILTER = 16
RAYLEIGH CRITERION PARAMETER = 0.80

AVX= -1.188 SDX= 5.787 RMS(RESID ER)= 5.37329 MTX COND=0.3359
AVY= -2.874 SDY=14.351 RMS(RESID ER)=13.40078 MTX COND=0.3359

Table 3-2: Harmonic tidal analysis of VACM V1 currents. Inclination is counterclockwise from east.

FINAL ANALYSIS RESULTS IN CURRENT ELLIPSE FORM

FOR STATION 2971-, OFFSHORE MOORING NORTH,LOCATED AT 39 39.60, -74 7.70
OVER THE PERIOD OF 850326,230000 TO 850507,200000

NODAL MODULATION AND INFERENCE CORRECTIONS HAVE BEEN MADE
AMPLITUDES HAVE BEEN SCALED TO COMPENSATE FOR THE PRIOR APPLICATION OF MOVING AVERAGE FILTERS
PHASES ARE GREENWICH

	NAME	FREQ (CPH)	MAJOR	ERR	MINOR	ERR	INC	ERR	PHASE	ERR	
1	Z0	0.00000000	2.989	0.309	0.000	0.360	32.7	7.2	180.0	5.6	
2	MM	0.00151215	2.983	3.305	-0.053	1.416	89.5	26.5	37.2	65.3	
3	MSF	0.00282193	2.174	3.182	-1.438	1.641	71.6	124.5	105.0	154.6	
4	ALP1	0.03439657	1.988	0.430	-0.543	0.422	46.2	13.6	307.8	13.9	
5	2Q1	0.03570635	1.441	0.747	-0.720	0.306	80.9	25.6	19.5	40.3	
6	Q1	0.03721850	1.413	0.748	0.507	0.302	98.2	18.8	194.6	35.1	
7	O1	0.03873065	3.445	0.658	0.605	0.462	58.4	8.2	265.8	11.4	
8	NO1	0.04026860	0.667	0.353	-0.123	0.491	32.4	44.0	260.1	32.4	
9	P1	0.04155259	1.115	0.651	-0.379	0.379	65.6	13.8	281.3	20.9	INF FR K1
10	K1	0.04178075	3.368	0.597	-1.145	0.347	65.6	13.8	281.3	20.9	
11	J1	0.04329290	1.315	0.299	0.600	0.778	4.1	43.5	250.2	25.6	
12	OO1	0.04483084	0.435	0.487	0.189	0.239	107.7	51.6	208.1	80.8	
13	UPS1	0.04634299	0.977	0.435	0.167	0.358	52.4	22.1	292.3	26.6	
14	EPS2	0.07617731	1.072	0.361	-0.340	0.345	48.1	21.6	274.0	22.4	
15	MU2	0.07768947	0.409	0.279	0.154	0.418	167.5	70.3	227.8	52.3	
16	N2	0.07899925	0.771	0.381	0.257	0.325	124.0	29.2	248.9	33.1	
17	M2	0.08051140	2.760	0.422	-0.525	0.274	83.1	6.1	266.6	9.2	
18	L2	0.08202355	0.722	0.440	-0.441	0.513	34.3	73.5	263.4	68.5	
19	S2	0.08333334	0.713	0.506	0.215	0.330	98.4	16.3	327.3	23.2	
20	K2	0.08356149	0.194	0.418	0.058	0.273	98.4	16.3	327.3	23.2	INF FR S2
21	ETA2	0.08507364	0.294	0.301	-0.059	0.219	111.5	46.2	118.6	61.8	
22	MO3	0.11924206	0.460	0.170	-0.066	0.182	78.0	23.4	229.2	21.9	
23	M3	0.12076710	0.303	0.211	-0.046	0.202	152.7	39.5	141.8	41.2	
24	MK3	0.12229215	0.259	0.178	-0.056	0.190	101.5	45.1	13.1	42.4	
25	SK3	0.12511408	0.451	0.178	-0.317	0.174	36.6	54.2	263.2	54.6	
26	MN4	0.15951064	0.266	0.160	-0.027	0.137	77.5	30.0	74.2	34.9	
27	M4	0.16102280	0.133	0.163	-0.051	0.138	97.2	76.4	170.3	86.4	
28	SN4	0.16233258	0.192	0.149	0.051	0.147	48.2	48.5	231.5	49.3	
29	MS4	0.16384473	0.651	0.154	0.006	0.137	66.4	12.0	52.9	13.5	
30	S4	0.16666667	0.380	0.136	0.043	0.142	37.5	21.7	298.3	20.8	
31	2MK5	0.20280355	0.273	0.135	-0.041	0.134	76.2	29.2	125.6	29.3	
32	2SK5	0.20844741	0.267	0.129	0.008	0.128	79.6	27.5	55.7	27.6	
33	2MN6	0.24002205	0.368	0.147	0.058	0.148	48.8	24.0	210.1	23.8	
34	M6	0.24153420	0.502	0.145	-0.099	0.150	61.1	18.1	236.1	17.6	
35	2MS6	0.24435614	0.253	0.143	0.002	0.140	35.8	31.7	260.1	32.3	
36	2SM6	0.24717806	0.269	0.139	-0.135	0.136	35.1	43.6	174.5	44.1	
37	3MK7	0.28331494	0.172	0.091	-0.053	0.097	171.9	37.1	207.8	35.2	
38	M8	0.32204559	0.218	0.097	0.006	0.081	21.5	21.3	153.9	25.4	

NO. PTS= 1006 NO. VALID X,Y PTS= 1005 1005

ORIGINAL DT =0.062500 HOURS DATA FILTER = 16
RAYLEIGH CRITERION PARAMETER = 0.80

AVX= -2.561 SDX= 6.273 RMS(RESID ER)= 5.75692 MTX COND=0.3350
AVY= -1.575 SDY=11.523 RMS(RESID ER)=10.82415 MTX COND=0.3350

Table 3-3: Harmonic tidal analysis of VACM V2 currents. Inclination is counterclockwise from east.

FINAL ANALYSIS RESULTS IN CURRENT ELLIPSE FORM

FOR STATION 63512, 635-12 ,LOCATED AT 39 36.01, -74 11.89
OVER THE PERIOD OF 850327,200000 TO 850507,100000

NODAL MODULATION AND INFERENCE CORRECTIONS HAVE BEEN MADE
AMPLITUDES HAVE BEEN SCALED TO COMPENSATE FOR THE PRIOR APPLICATION OF MOVING AVERAGE FILTERS
PHASES ARE GREENWICH

	NAME	FREQ (CPH)	MAJOR	ERR	MINOR	ERR	INC	ERR	PHASE	ERR	
1	Z0	0.00000000	2.428	0.157	0.000	0.441	176.3	11.0	360.0	3.5	
2	MM	0.00151215	3.771	4.518	-0.799	0.662	92.4	18.6	39.3	72.4	
3	MSF	0.00282193	3.591	4.524	-0.166	0.621	88.4	10.7	89.0	70.0	
4	ALP1	0.03439657	0.893	0.544	-0.591	0.257	108.7	50.5	289.1	65.2	
5	2Q1	0.03570635	1.672	0.811	0.116	0.474	72.6	16.4	353.2	28.1	
6	Q1	0.03721850	1.291	0.695	0.078	0.638	48.9	28.6	125.3	30.9	
7	O1	0.03873065	3.354	0.823	0.188	0.450	77.1	7.7	252.9	14.1	
8	NO1	0.04026860	0.349	0.622	-0.037	0.336	77.8	57.0	225.7	103.6	
9	P1	0.04155259	0.286	0.775	0.179	0.420	77.4	114.2	156.4	145.4	INF FR K1
10	K1	0.04178075	0.864	0.711	0.541	0.385	77.4	114.2	156.4	145.4	
11	J1	0.04329290	0.929	0.840	0.124	0.494	71.9	31.8	255.3	52.9	
12	OO1	0.04483084	0.078	0.562	0.043	0.294	99.1	81.0	248.7	247.6	
13	UPS1	0.04634299	0.598	0.566	-0.176	0.337	71.4	39.4	272.3	60.4	
14	EPS2	0.07617731	0.220	0.265	0.018	0.293	95.7	77.0	310.1	69.5	
15	MU2	0.07768947	0.539	0.265	0.247	0.295	86.4	42.9	129.6	40.1	
16	N2	0.07899925	0.472	0.284	0.078	0.274	35.0	34.7	69.4	35.9	
17	M2	0.08051140	1.125	0.284	0.464	0.281	138.2	18.7	231.5	18.8	
18	L2	0.08202355	0.434	0.356	0.150	0.395	88.8	62.1	12.1	57.2	
19	S2	0.08333334	0.291	0.320	-0.009	0.356	90.4	35.5	294.3	32.0	
20	K2	0.08356149	0.079	0.264	-0.002	0.294	90.4	35.5	294.3	32.0	INF FR S2
21	ETA2	0.08507364	0.342	0.218	-0.092	0.198	168.0	37.4	97.3	40.6	
22	MO3	0.11924206	0.386	0.119	-0.065	0.162	91.2	24.9	330.4	18.7	
23	M3	0.12076710	0.252	0.173	-0.189	0.159	36.3	107.5	86.9	110.1	
24	MK3	0.12229215	0.347	0.126	-0.088	0.168	99.6	30.2	225.8	23.5	
25	SK3	0.12511408	0.090	0.152	0.028	0.131	30.4	98.3	301.5	110.6	
26	MN4	0.15951064	0.201	0.158	0.008	0.202	151.0	57.8	283.1	45.2	
27	M4	0.16102280	0.286	0.212	0.044	0.151	67.6	31.8	156.3	43.7	
28	SN4	0.16233258	0.418	0.216	0.019	0.134	84.0	18.4	233.3	29.7	
29	MS4	0.16384473	0.305	0.215	0.094	0.131	89.1	30.5	49.1	45.3	
30	S4	0.16666667	0.226	0.190	0.084	0.145	62.6	47.7	218.8	58.3	
31	2MK5	0.20280355	0.139	0.109	-0.047	0.094	62.8	46.4	28.3	52.7	
32	2SK5	0.20844741	0.182	0.106	-0.029	0.087	68.4	28.6	6.4	34.6	
33	2MN6	0.24002205	0.188	0.131	0.034	0.075	73.5	24.7	207.9	41.5	
34	M6	0.24153420	0.228	0.126	-0.039	0.083	65.2	22.2	190.3	32.8	
35	2MS6	0.24435614	0.164	0.078	-0.053	0.122	23.3	48.4	253.8	34.0	
36	2SM6	0.24717806	0.162	0.122	0.013	0.070	73.5	25.0	285.5	43.4	
37	3MK7	0.28331494	0.054	0.071	0.026	0.071	45.8	107.2	44.8	107.6	
38	M8	0.32204559	0.138	0.097	0.069	0.089	113.6	56.1	98.4	59.3	

NO. PTS= 975 NO. VALID X,Y PTS= 975 975

ORIGINAL DT =0.062500 HOURS DATA FILTER = 16
RAYLEIGH CRITERION PARAMETER = 0.80

AVX= -2.606 SDX= 3.696 RMS(RESID ER)= 3.50876 MTX COND=0.3253
AVY= 0.103 SDY=13.029 RMS(RESID ER)=12.53046 MTX COND=0.3253

Table 3-4: Harmonic tidal analysis of Wave Gauge W1 currents. Inclination is counterclockwise from east.

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1ANALYSIS OF HOURLY TIDAL HEIGHTS  STN 63512  NJX  635-12
 FROM 850327.190923 TO 850507.100923    AT THE LOCATION  39 36.01, -74 11.89
 NO.OBS.=    976     NO.PTS.ANAL.=    976     MIDPT=850417. 20923  SEPARATION =0.80
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NO	NAME	FREQ (CPH)	AMP	ERR	PHASE-G	ERR	
1	Z0	0.00000000	6.3	0.0	0.0	0.0	
2	MM	0.00151215	0.0	0.0	300.9	122.0	
3	MSF	0.00282193	0.0	0.0	278.8	258.1	
4	ALP1	0.03439657	0.0	0.0	108.0	52.6	
5	2Q1	0.03570635	0.0	0.0	206.0	52.5	
6	Q1	0.03721850	0.0	0.0	93.5	95.2	
7	O1	0.03873065	0.1	0.0	158.6	6.5	
8	NO1	0.04026860	0.0	0.0	161.3	143.1	
9	P1	0.04155259	0.0	0.0	178.3	7.0	INF FR K1
10	K1	0.04178075	0.1	0.0	166.3	7.0	
11	J1	0.04329290	0.0	0.0	112.4	44.5	
12	OO1	0.04483084	0.0	0.0	150.6	66.0	
13	UPS1	0.04634299	0.0	0.0	168.4	32.5	
14	EPS2	0.07617731	0.0	0.1	200.0	103.0	
15	MU2	0.07768947	0.1	0.1	266.8	60.2	
16	N2	0.07899925	0.1	0.1	300.2	28.0	
17	M2	0.08051140	0.5	0.1	334.6	6.9	
18	L2	0.08202355	0.1	0.1	36.4	68.1	
19	S2	0.08333334	0.1	0.1	352.6	32.2	
20	K2	0.08356149	0.0	0.1	352.8	32.2	INF FR S2
21	ETA2	0.08507364	0.0	0.0	333.4	71.6	
22	MO3	0.11924206	0.0	0.0	11.5	30.9	
23	M3	0.12076710	0.0	0.0	43.0	38.4	
24	MK3	0.12229215	0.0	0.0	62.1	59.1	
25	SK3	0.12511408	0.0	0.0	48.5	43.7	
26	MN4	0.15951064	0.0	0.0	341.0	20.8	
27	M4	0.16102280	0.0	0.0	143.9	42.9	
28	SN4	0.16233258	0.0	0.0	347.9	122.4	
29	MS4	0.16384473	0.0	0.0	122.1	30.5	
30	S4	0.16666667	0.0	0.0	86.7	135.9	
31	2MK5	0.20280355	0.0	0.0	323.2	48.2	
32	2SK5	0.20844741	0.0	0.0	6.8	27.6	
33	2MN6	0.24002205	0.0	0.0	82.1	212.3	
34	M6	0.24153420	0.0	0.0	331.6	55.9	
35	2MS6	0.24435614	0.0	0.0	46.0	65.5	
36	2SM6	0.24717806	0.0	0.0	85.4	103.2	
37	3MK7	0.28331494	0.0	0.0	131.6	64.3	
38	M8	0.32204559	0.0	0.0	31.6	120.1	

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NUMBER OF VALID DATA =    975  AVERAGE =       6.34
STANDARD DEVIATION =    0.45  THEORETICAL RMS =     0.19  MATRIX CONDITION =  0.33

AMPLITUDES HAVE BEEN SCALED TO COMPENSATE FOR THE PRIOR APPLICATION OF MOVING AVERAGE FILTERS
ORIGINAL DT=0.06250 HR    DATA FILTER = 16

AFTER INFERENCE, RMS(RESID ERROR)= 0.19184
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Table 3-5: Harmonic tidal analysis of pressure time series from Wave Gauge W1. Phase is Greenwich.

ANALYSIS OF HOURLY TIDAL HEIGHTS STN 136A1 NJX T2 TDR 136
FROM 850327.172304 TO 850508.152304 AT THE LOCATION 39 35.20, -74 13.00
NO.OBS.= 1007 NO.PTS.ANAL.= 1007 MIDPT=850417.162304 SEPARATION =0.80

NO	NAME	FREQ (CPH)	AMP	ERR	PHASE-G	ERR	
1	Z0	0.00000000	2.5	0.0	0.0	0.1	
2	MM	0.00151215	0.0	0.0	307.7	67.9	
3	MSF	0.00282193	0.0	0.0	287.7	173.5	
4	ALP1	0.03439657	0.0	0.0	123.4	36.0	
5	2Q1	0.03570635	0.0	0.0	198.8	24.4	
6	Q1	0.03721850	0.0	0.0	122.5	39.1	
7	O1	0.03873065	0.1	0.0	166.8	3.0	
8	NO1	0.04026860	0.0	0.0	176.9	19.8	
9	P1	0.04155259	0.0	0.0	187.9	2.9	INF FR K1
10	K1	0.04178075	0.1	0.0	175.9	2.9	
11	J1	0.04329290	0.0	0.0	164.0	20.3	
12	OO1	0.04483084	0.0	0.0	230.1	42.1	
13	UPS1	0.04634299	0.0	0.0	197.0	20.4	
14	EPS2	0.07617731	0.0	0.0	336.1	21.3	
15	MU2	0.07768947	0.0	0.0	334.5	6.2	
16	N2	0.07899925	0.2	0.0	334.3	1.5	
17	M2	0.08051140	0.6	0.0	352.4	0.5	
18	L2	0.08202355	0.0	0.0	331.1	15.6	
19	S2	0.08333334	0.1	0.0	24.4	1.6	
20	K2	0.08356149	0.0	0.0	24.6	1.6	INF FR S2
21	ETA2	0.08507364	0.0	0.0	19.5	64.2	
22	MO3	0.11924206	0.0	0.0	11.8	20.5	
23	M3	0.12076710	0.0	0.0	69.9	19.3	
24	MK3	0.12229215	0.0	0.0	315.1	75.6	
25	SK3	0.12511408	0.0	0.0	1.1	24.2	
26	MN4	0.15951064	0.0	0.0	139.6	18.7	
27	M4	0.16102280	0.0	0.0	180.6	9.7	
28	SN4	0.16233258	0.0	0.0	161.8	43.5	
29	MS4	0.16384473	0.0	0.0	174.5	12.1	
30	S4	0.16666667	0.0	0.0	257.9	61.5	
31	2MK5	0.20280355	0.0	0.0	14.2	51.2	
32	2SK5	0.20844741	0.0	0.0	9.6	31.8	
33	2MN6	0.24002205	0.0	0.0	16.3	11.5	
34	M6	0.24153420	0.0	0.0	30.7	8.2	
35	2MS6	0.24435614	0.0	0.0	62.6	11.1	
36	2SM6	0.24717806	0.0	0.0	100.8	28.1	
37	3MK7	0.28331494	0.0	0.0	210.1	28.7	
38	M8	0.32204559	0.0	0.0	309.3	28.4	

NUMBER OF VALID DATA = 1007 AVERAGE = 2.51
STANDARD DEVIATION = 0.47 THEORETICAL RMS = 0.11 MATRIX CONDITION = 0.34

AMPLITUDES HAVE BEEN SCALED TO COMPENSATE FOR THE PRIOR APPLICATION OF MOVING AVERAGE FILTERS
ORIGINAL DT=0.25000 HR DATA FILTER = 4

AFTER INFERENCE, RMS(RESID ERROR)= 0.11133

Table 3-6: Harmonic tidal analysis of pressure time series from TDR T2. Phase is Greenwich.

ANALYSIS OF HOURLY TIDAL HEIGHTS STN 101A1 NJX T3 TDR 101
FROM 850328.155320 TO 850426.215320 AT THE LOCATION 39 37.80, -74 11.20
NO.OBS.= 703 NO.PTS.ANAL.= 703 MIDPT=850412. 65320 SEPARATION =0.80

NO	NAME	FREQ (CPH)	AMP	ERR	PHASE-G	ERR	
1	Z0	0.00000000	6.0	0.0	0.0	0.0	
2	MM	0.00151215	0.0	0.0	276.3	56.6	
3	MSF	0.00282193	0.0	0.0	190.0	55.9	
4	ALP1	0.03439657	0.0	0.0	131.9	46.3	
5	2Q1	0.03570635	0.0	0.0	194.6	52.6	
6	Q1	0.03721850	0.0	0.0	304.7	242.0	
7	O1	0.03873065	0.1	0.0	169.6	4.0	
8	NO1	0.04026860	0.0	0.0	223.6	26.7	
9	P1	0.04155259	0.0	0.0	190.1	3.9	INF FR K1
10	K1	0.04178075	0.1	0.0	178.1	3.9	
11	J1	0.04329290	0.0	0.0	172.3	21.5	
12	OO1	0.04483084	0.0	0.0	269.3	37.3	
13	UPS1	0.04634299	0.0	0.0	175.2	20.4	
14	EPS2	0.07617731	0.0	0.0	318.1	51.8	
15	MU2	0.07768947	0.0	0.0	330.4	6.1	
16	N2	0.07899925	0.2	0.0	335.1	1.7	
17	M2	0.08051140	0.6	0.0	352.9	0.5	
18	L2	0.08202355	0.0	0.0	304.5	14.9	
19	S2	0.08333334	0.1	0.0	24.4	1.7	
20	K2	0.08356149	0.0	0.0	24.6	1.7	INF FR S2
21	ETA2	0.08507364	0.0	0.0	153.5	41.8	
22	MO3	0.11924206	0.0	0.0	352.7	22.7	
23	M3	0.12076710	0.0	0.0	102.7	22.2	
24	MK3	0.12229215	0.0	0.0	354.6	35.2	
25	SK3	0.12511408	0.0	0.0	352.0	20.4	
26	MN4	0.15951064	0.0	0.0	116.3	15.1	
27	M4	0.16102280	0.0	0.0	170.6	6.4	
28	SN4	0.16233258	0.0	0.0	228.3	68.6	
29	MS4	0.16384473	0.0	0.0	166.5	13.3	
30	S4	0.16666667	0.0	0.0	309.0	28.8	
31	2MK5	0.20280355	0.0	0.0	28.0	43.9	
32	2SK5	0.20844741	0.0	0.0	51.4	38.9	
33	2MN6	0.24002205	0.0	0.0	27.5	15.9	
34	M6	0.24153420	0.0	0.0	23.7	10.0	
35	2MS6	0.24435614	0.0	0.0	67.8	11.9	
36	2SM6	0.24717806	0.0	0.0	103.8	24.6	
37	3MK7	0.28331494	0.0	0.0	175.0	44.2	
38	M8	0.32204559	0.0	0.0	329.9	36.5	

NUMBER OF VALID DATA = 703 AVERAGE = 6.01
STANDARD DEVIATION = 0.45 THEORETICAL RMS = 0.09 MATRIX CONDITION = 0.80

AMPLITUDES HAVE BEEN SCALED TO COMPENSATE FOR THE PRIOR APPLICATION OF MOVING AVERAGE FILTERS
ORIGINAL DT=0.25000 HR DATA FILTER = 4

AFTER INFERENCE, RMS(RESID ERROR)= 0.09356

Table 3-7: Harmonic tidal analysis of pressure time series from TDR T3. Phase is Greenwich.

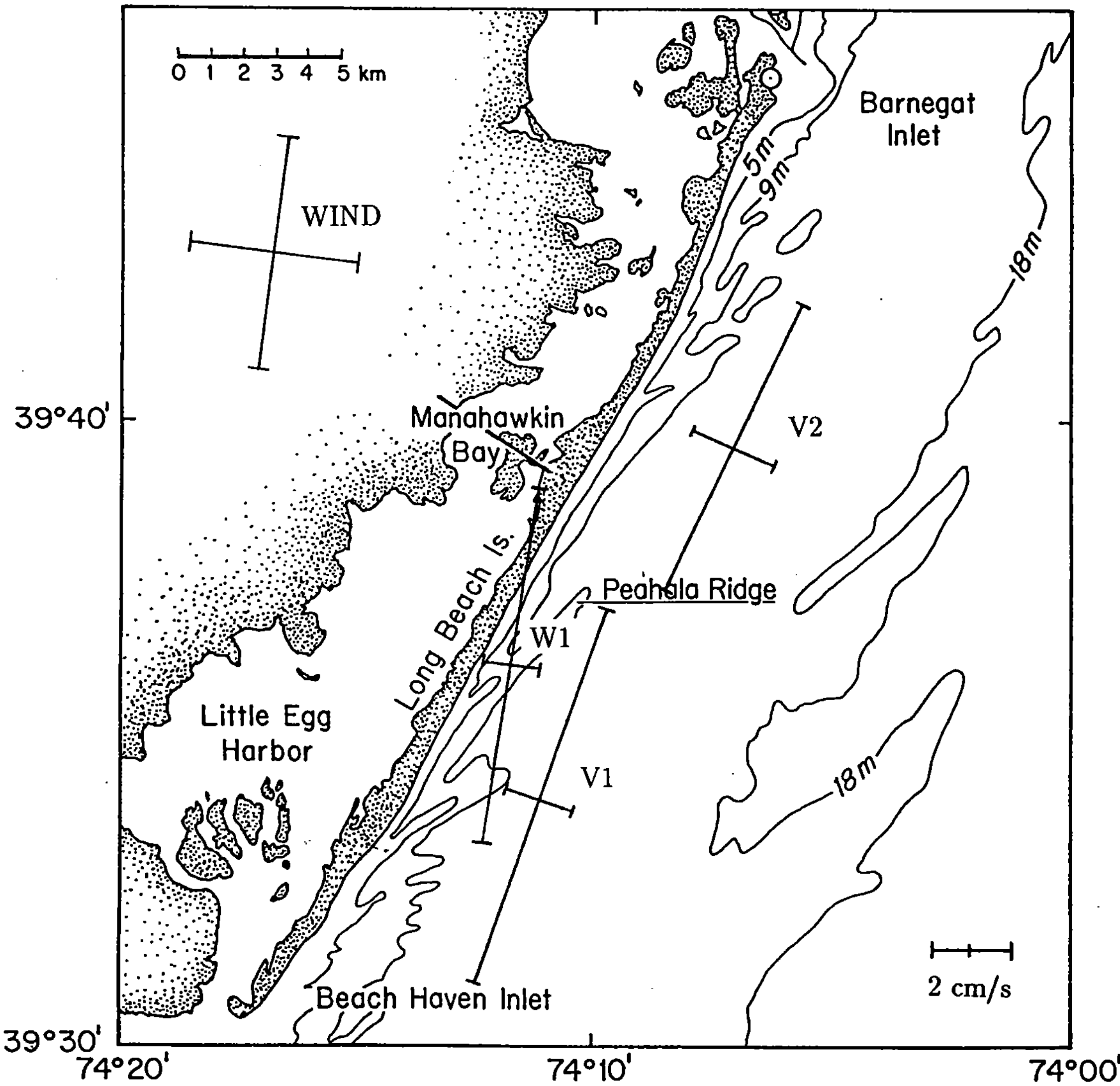

Figure 3.5: Major and minor axes of low-frequency variations of wind and currents. Current axes are scaled to show water particle excursions over a 12-hour period. Wind variance is 5.2 m/s and 3.1 m/s along the major and minor axes, respectively.

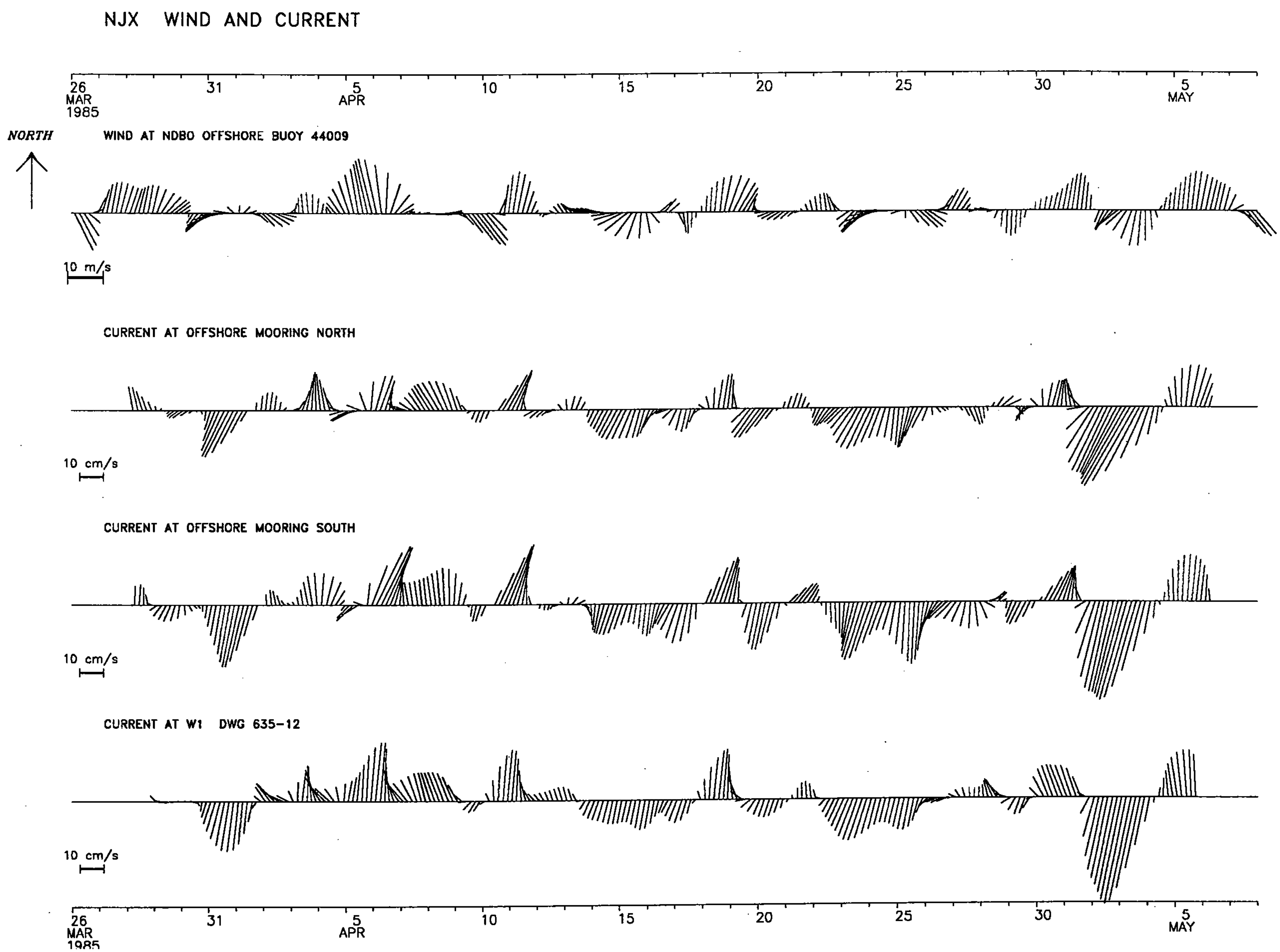

Figure 3.6: Low-pass filtered time series of wind from Weather Buoy 44009 and currents.

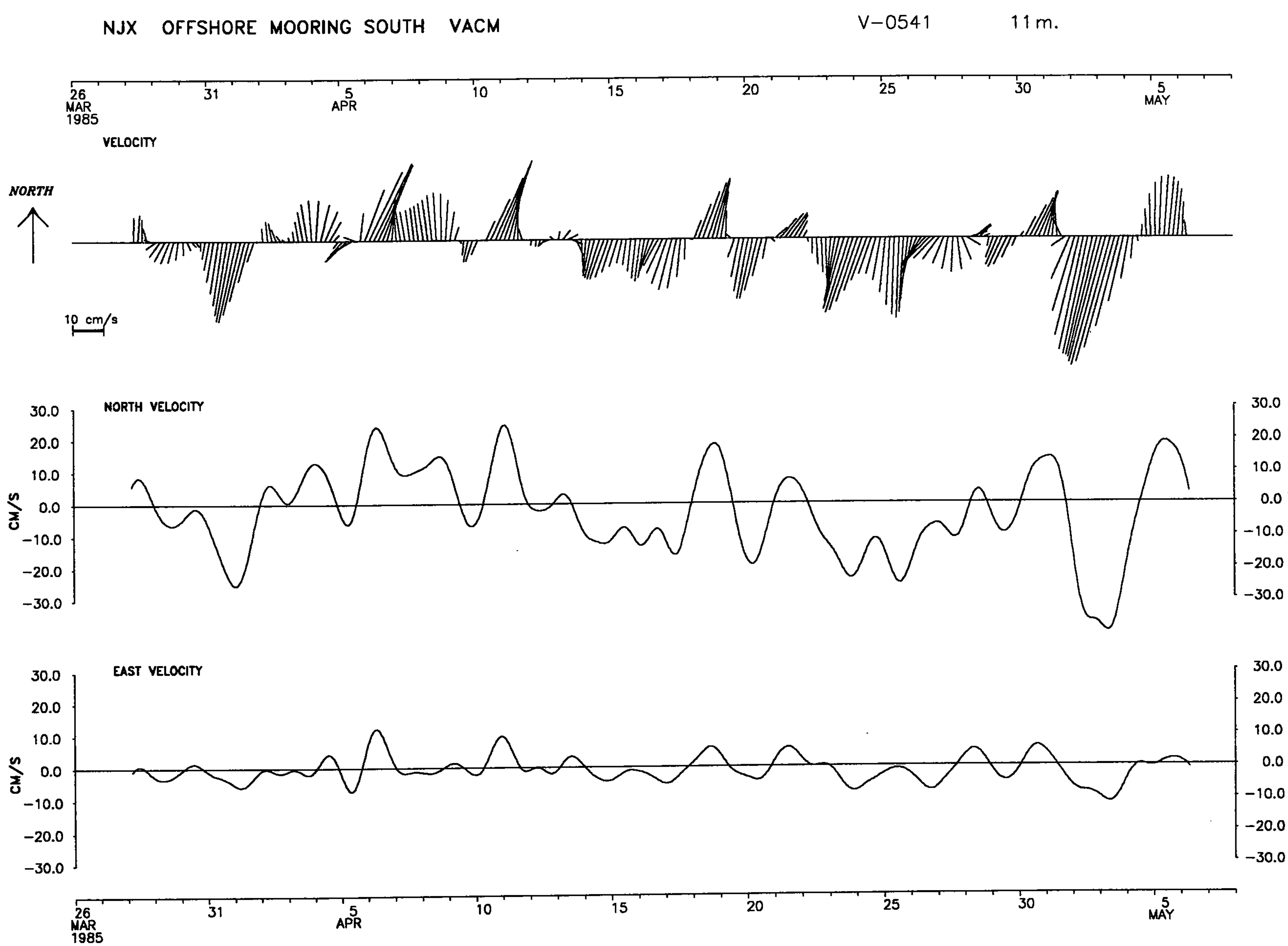

Figure 3.7: Low-pass filtered time series of current at 11 meters depth from station VACM V1.

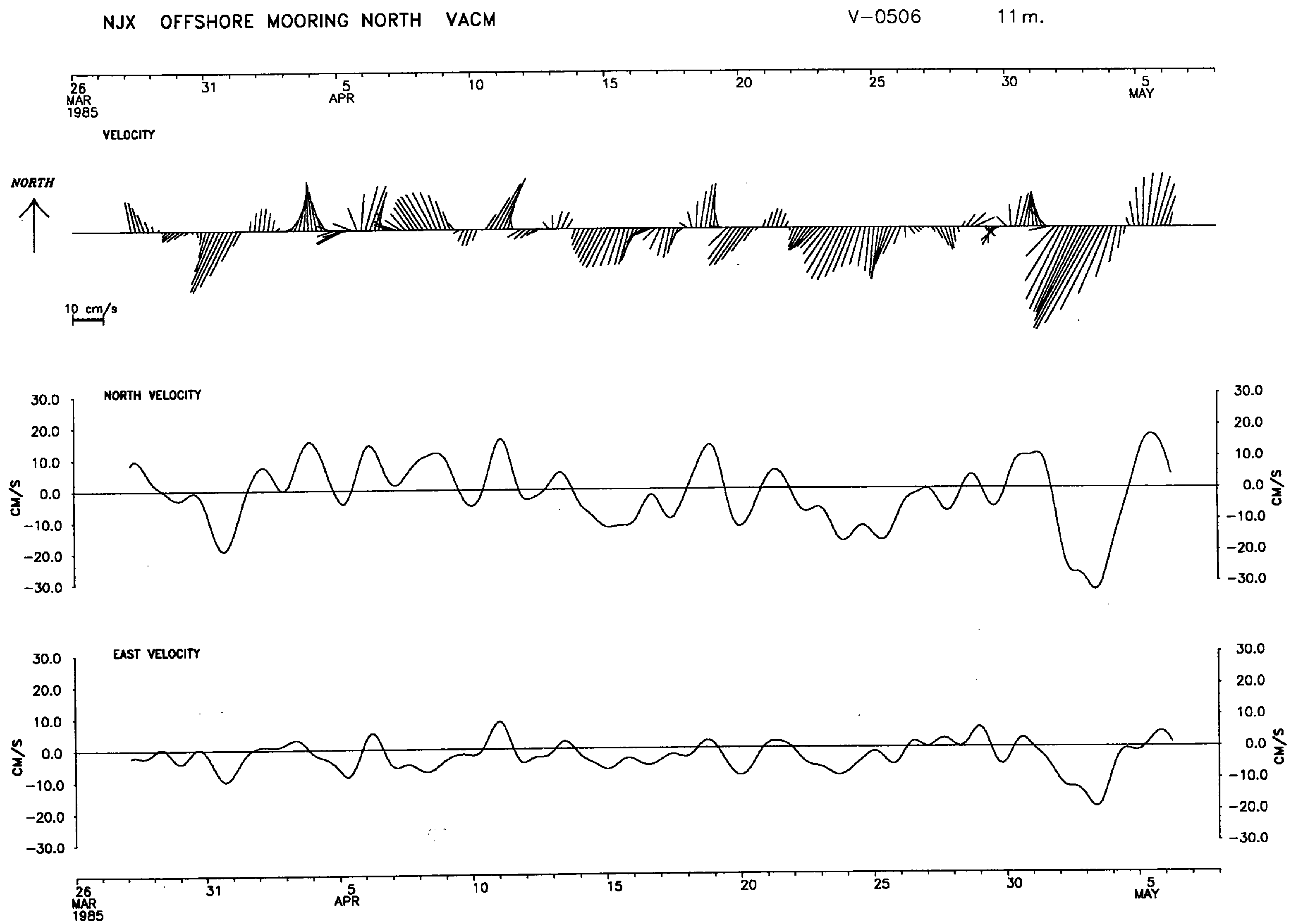

Figure 3.8: Low-pass filtered time series of current at 11 meters depth from station VACM V2.

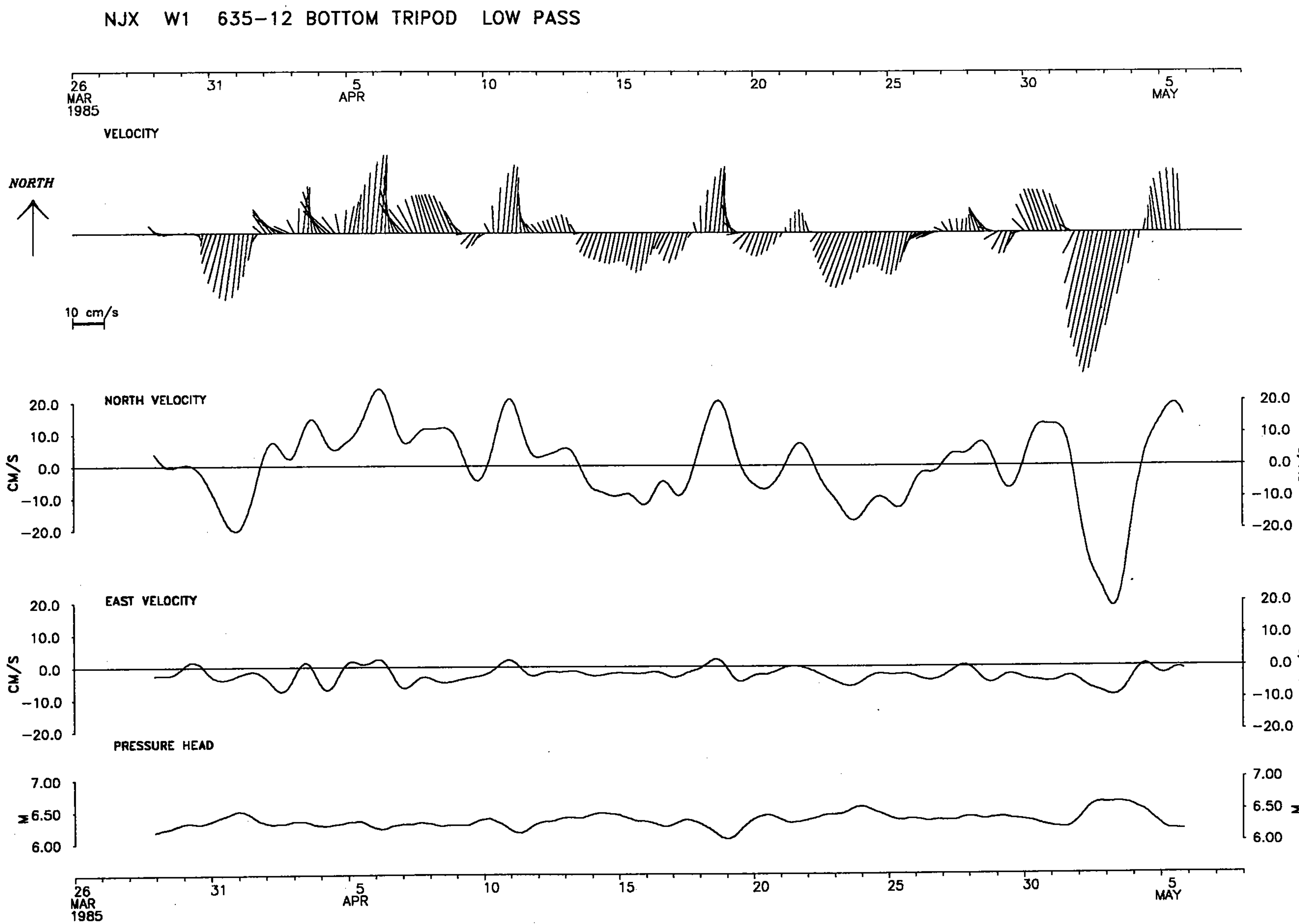

Figure 3.9: Low-pass filtered time series of current and pressure at 7 meters depth from station Wave Gauge W1.

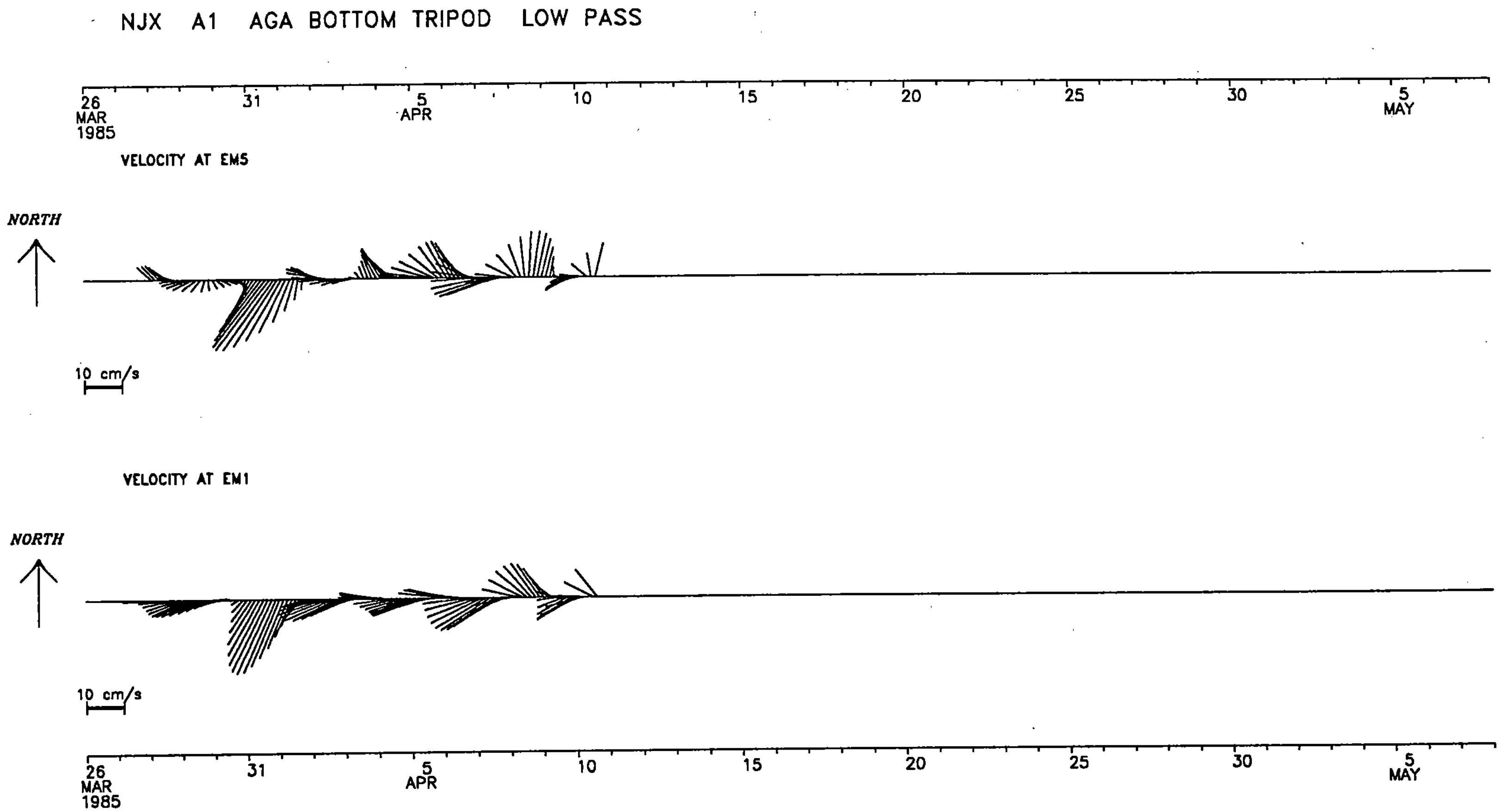

Figure 3.10: Low-pass filtered time series of current at 12 meters depth from station EMCM A1.

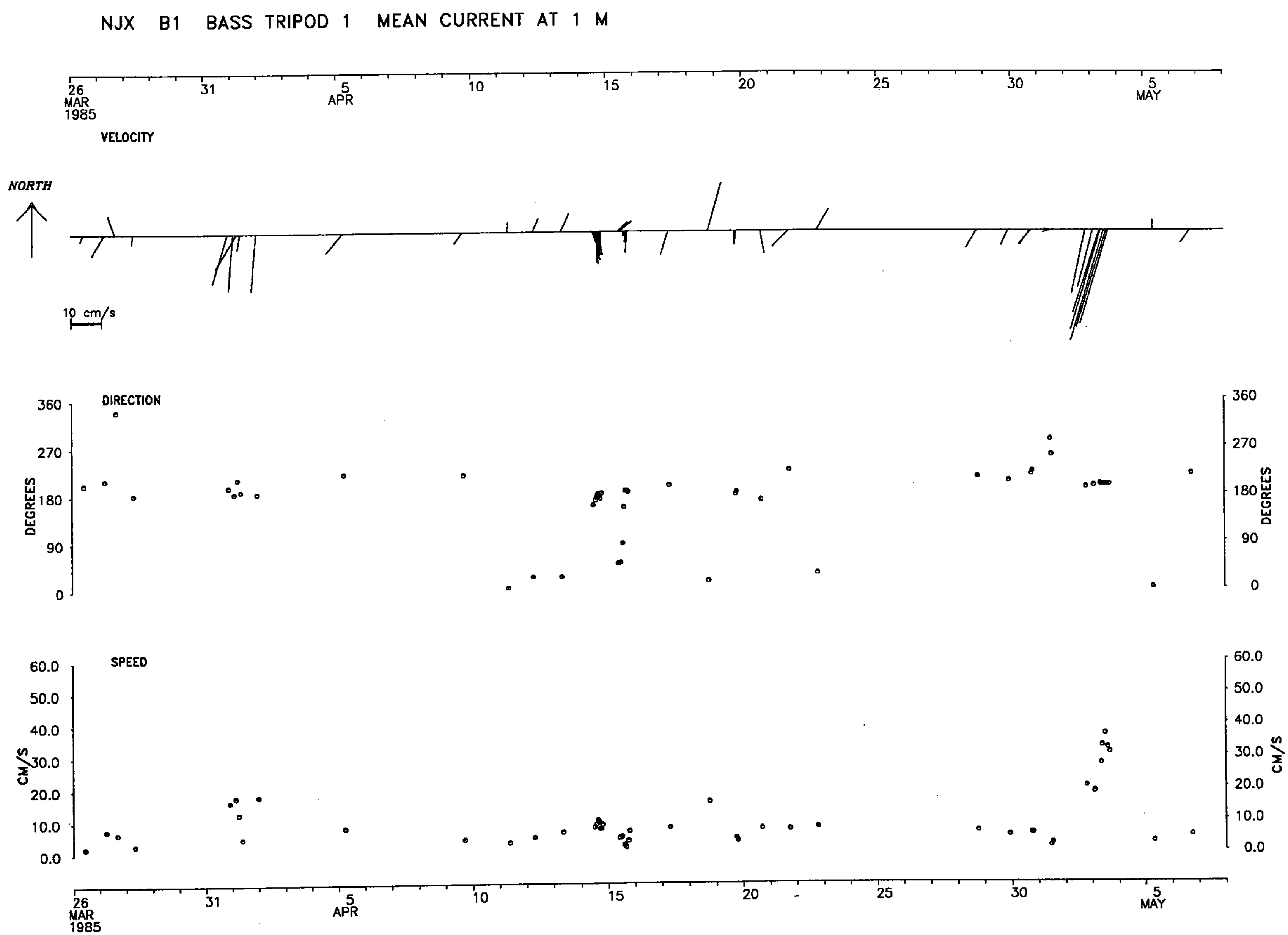

Figure 3.11: Mean currents for BASS tripod B1 taken from the sensor 1 m above the bottom. These are 20 minute averages.

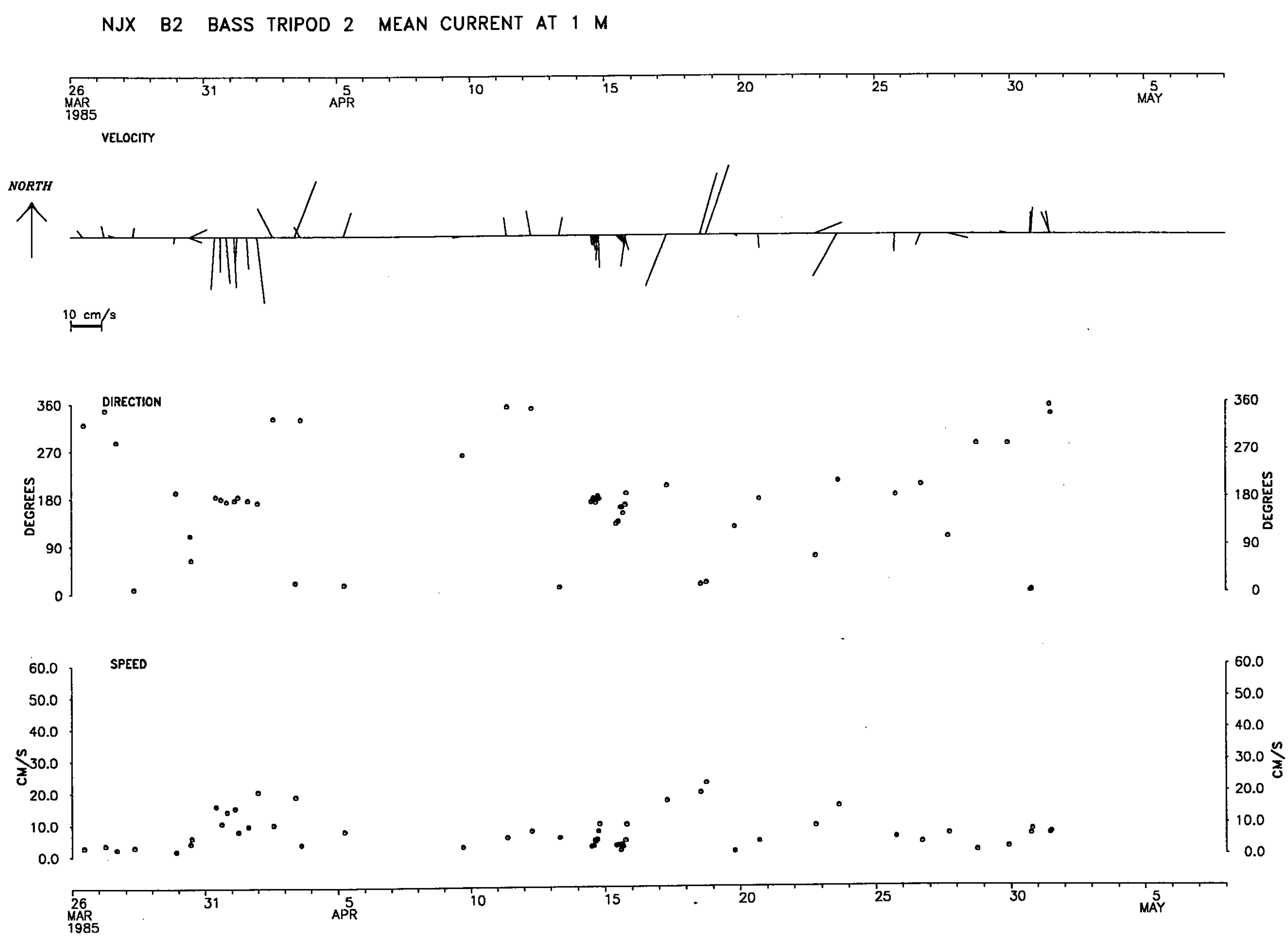

Figure 3.12: Mean currents for BASS tripod B2 taken from the sensor 1 m above the bottom. These are 20 minute averages.

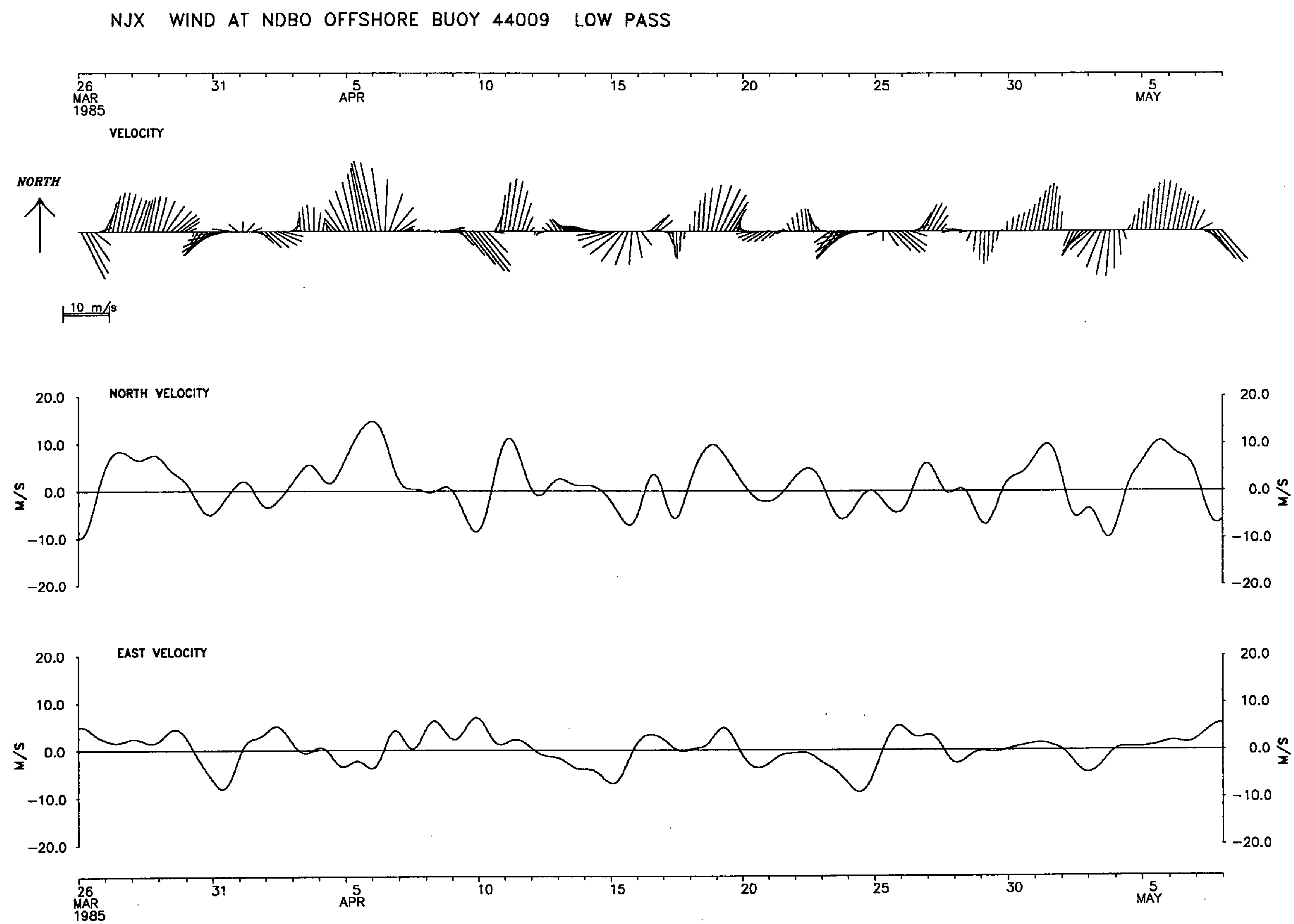

Figure 3.13: Low-pass filtered time series of wind from Weather Buoy 44009.

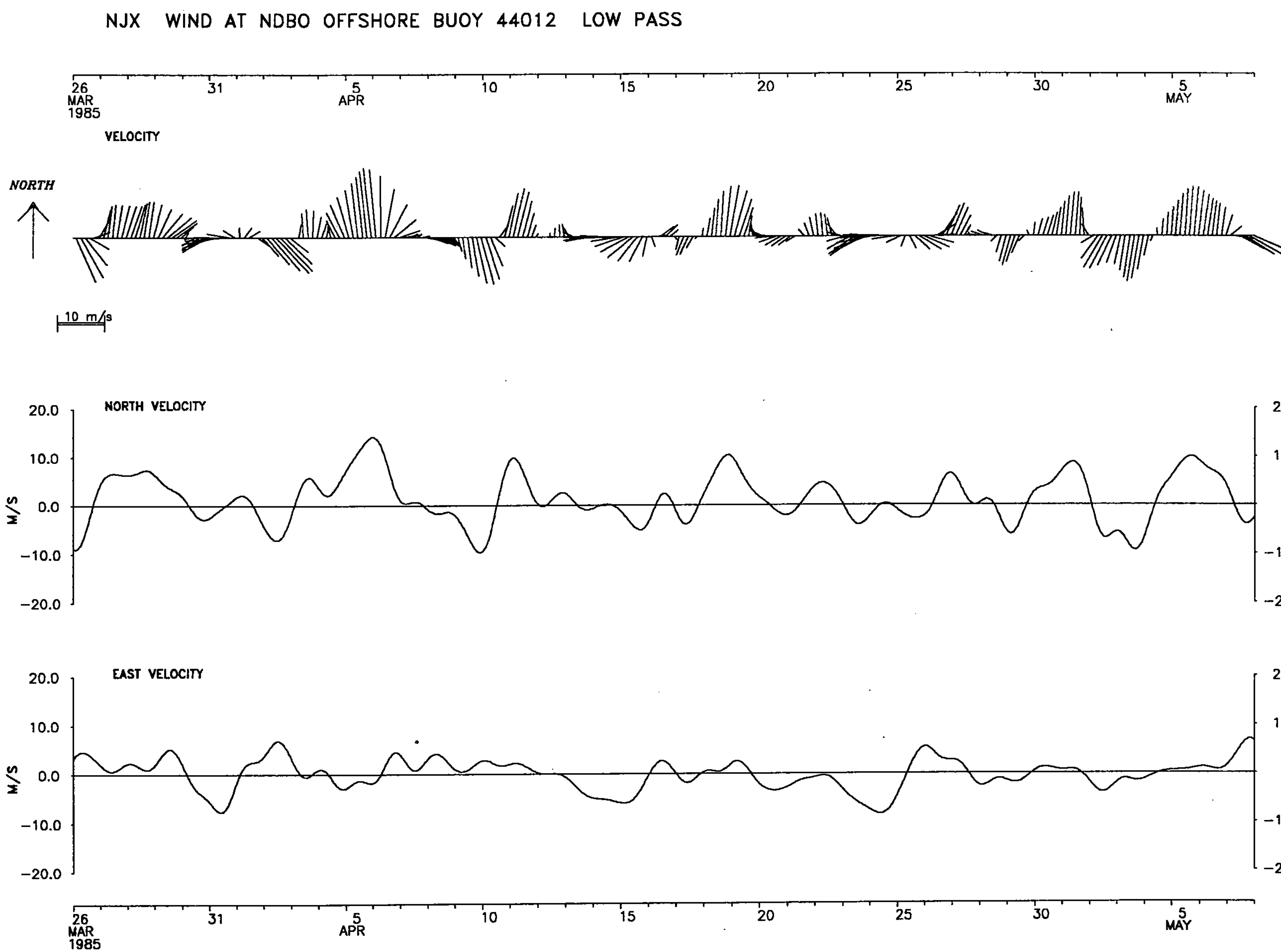

Figure 3.14: Low-pass filtered time series of wind from Weather Buoy 44012.

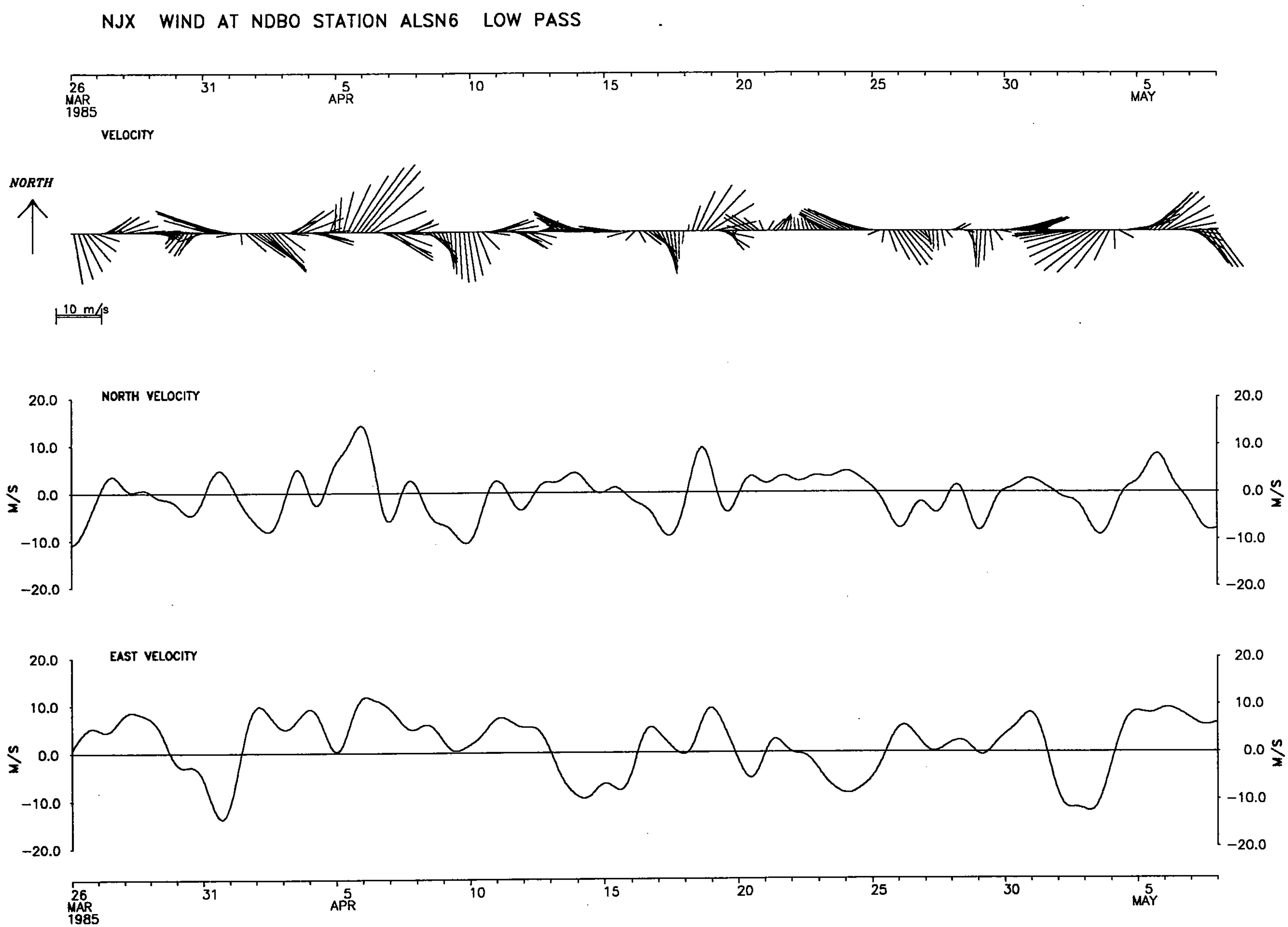

Figure 3.15: Low-pass filtered time series of wind from Weather Buoy ALSN6.

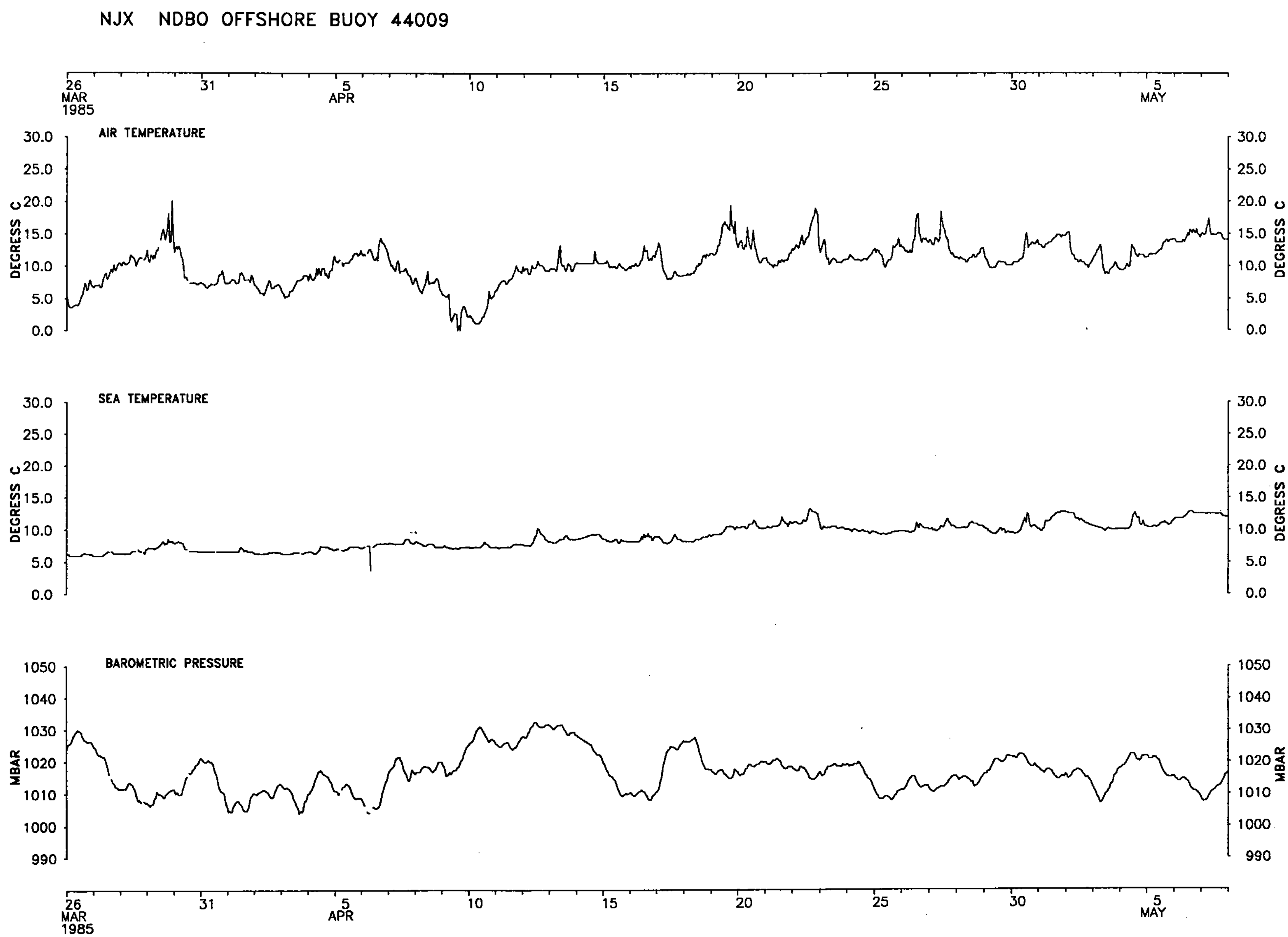

Figure 3.16: Hourly time series of air temperature, sea temperature and barometric pressure at Weather Buoy 44009.

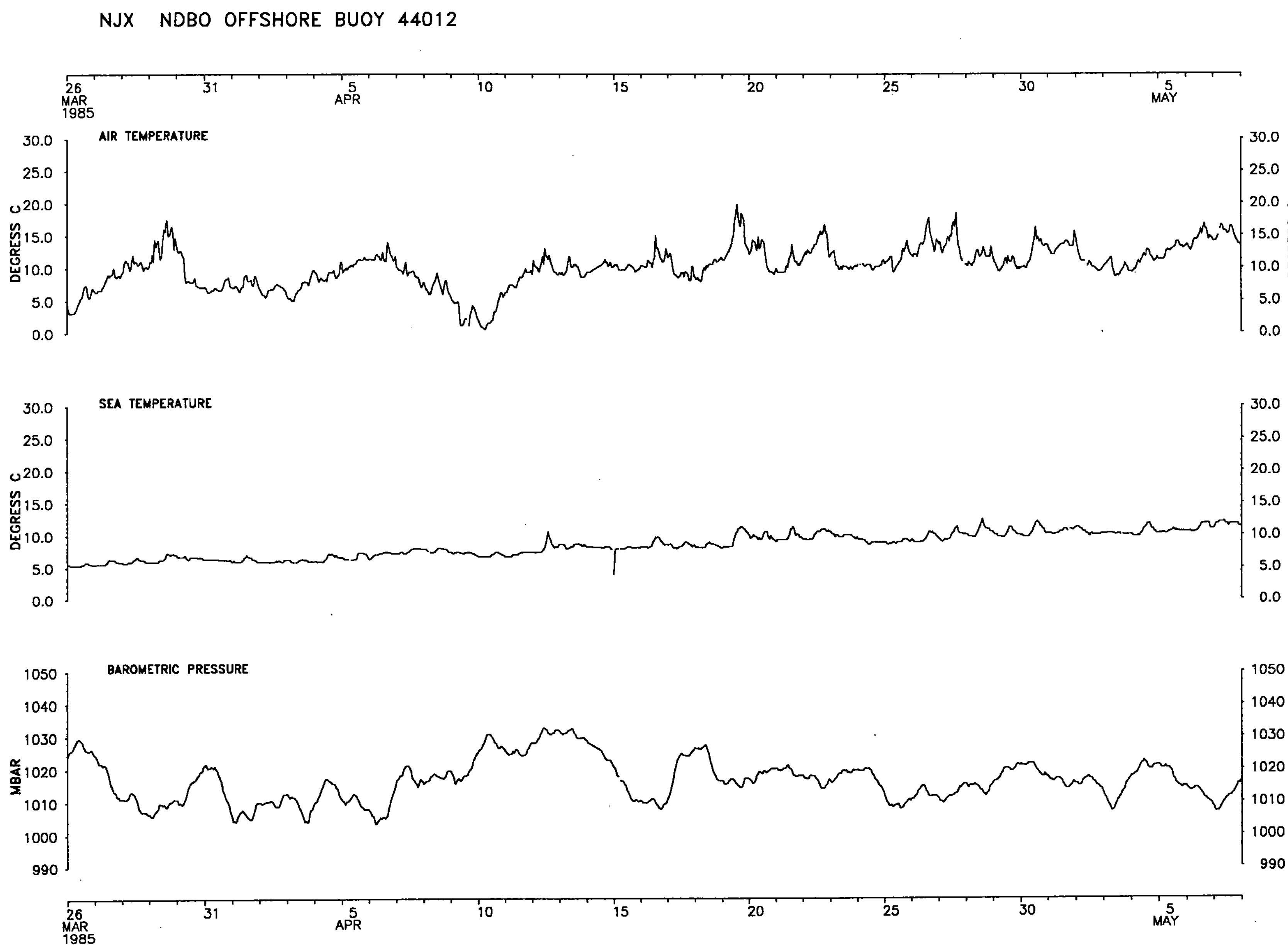

Figure 3.17: Hourly time series of air temperature, sea temperature and barometric pressure at Weather Buoy 44012.

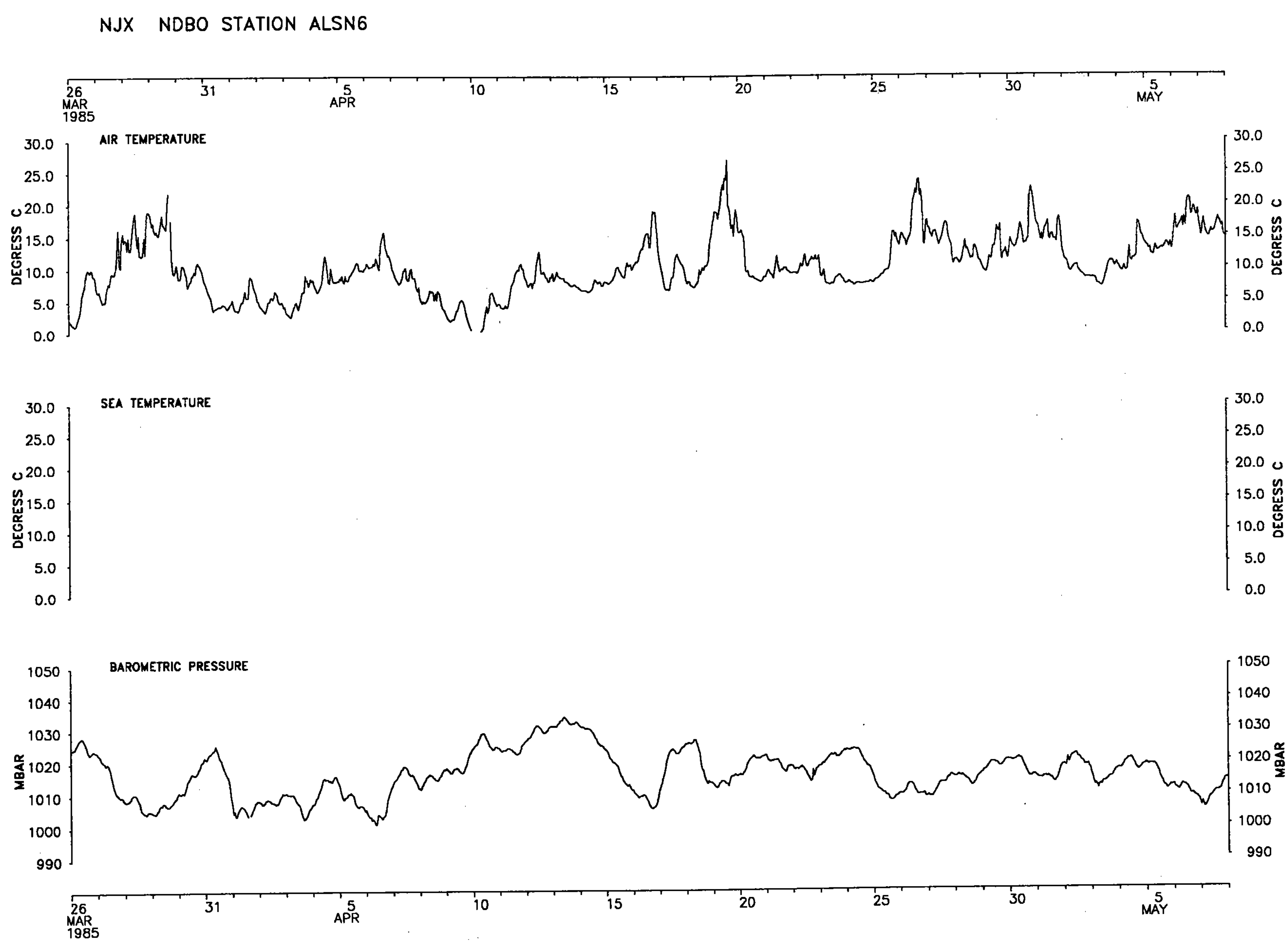

Figure 3.18: Hourly time series of air temperature, sea temperature and barometric pressure at Weather Buoy ALSN6. Note sea temperature was not available from this station.

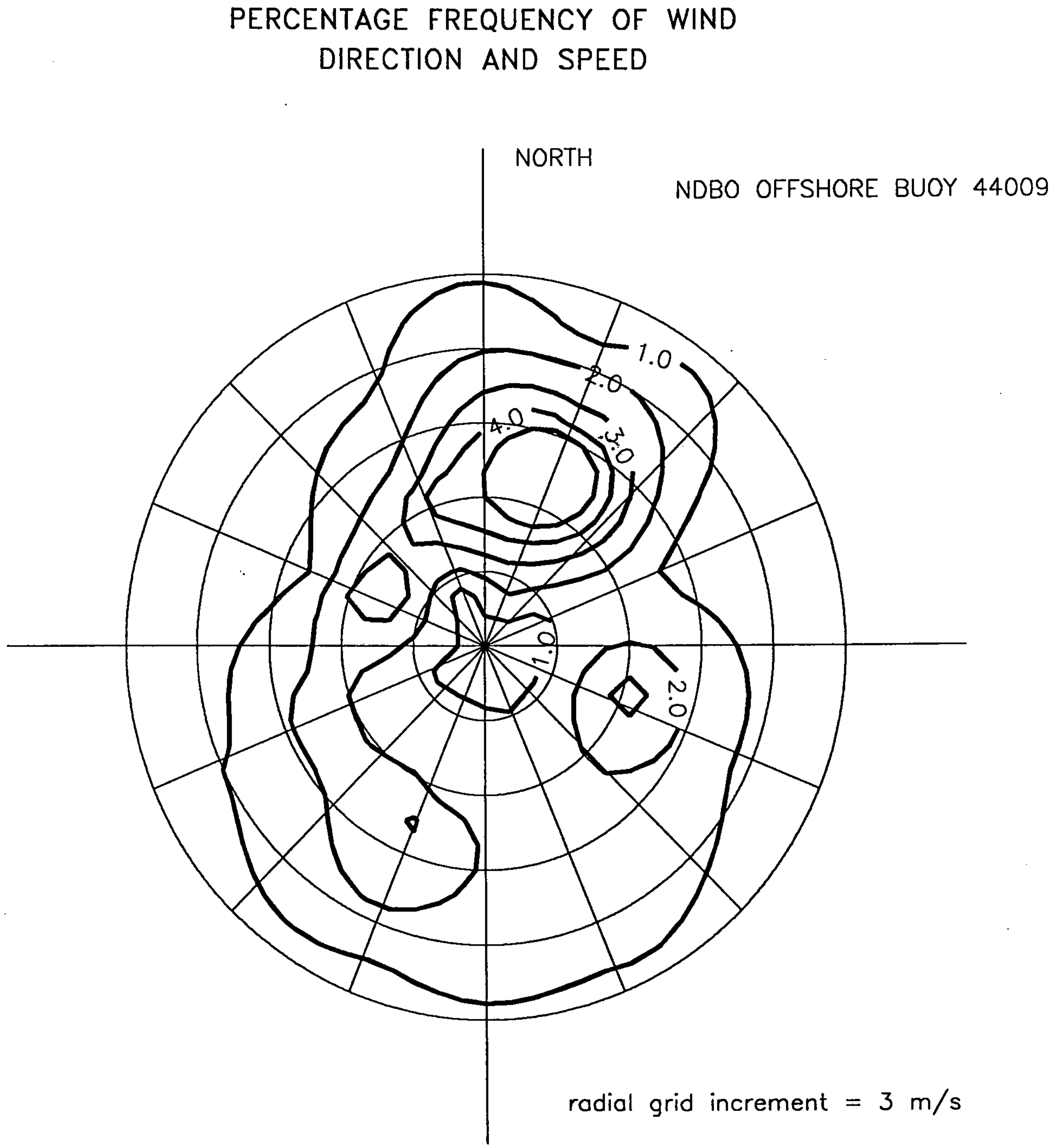

Figure 3.19: Wind rose from Weather Buoy 44009 wind data 26 Mar. - 7 May 1985. Plotted are contours of percentage of frequency of wind direction and speed. Oceanographic convention (wind toward the north is upward).

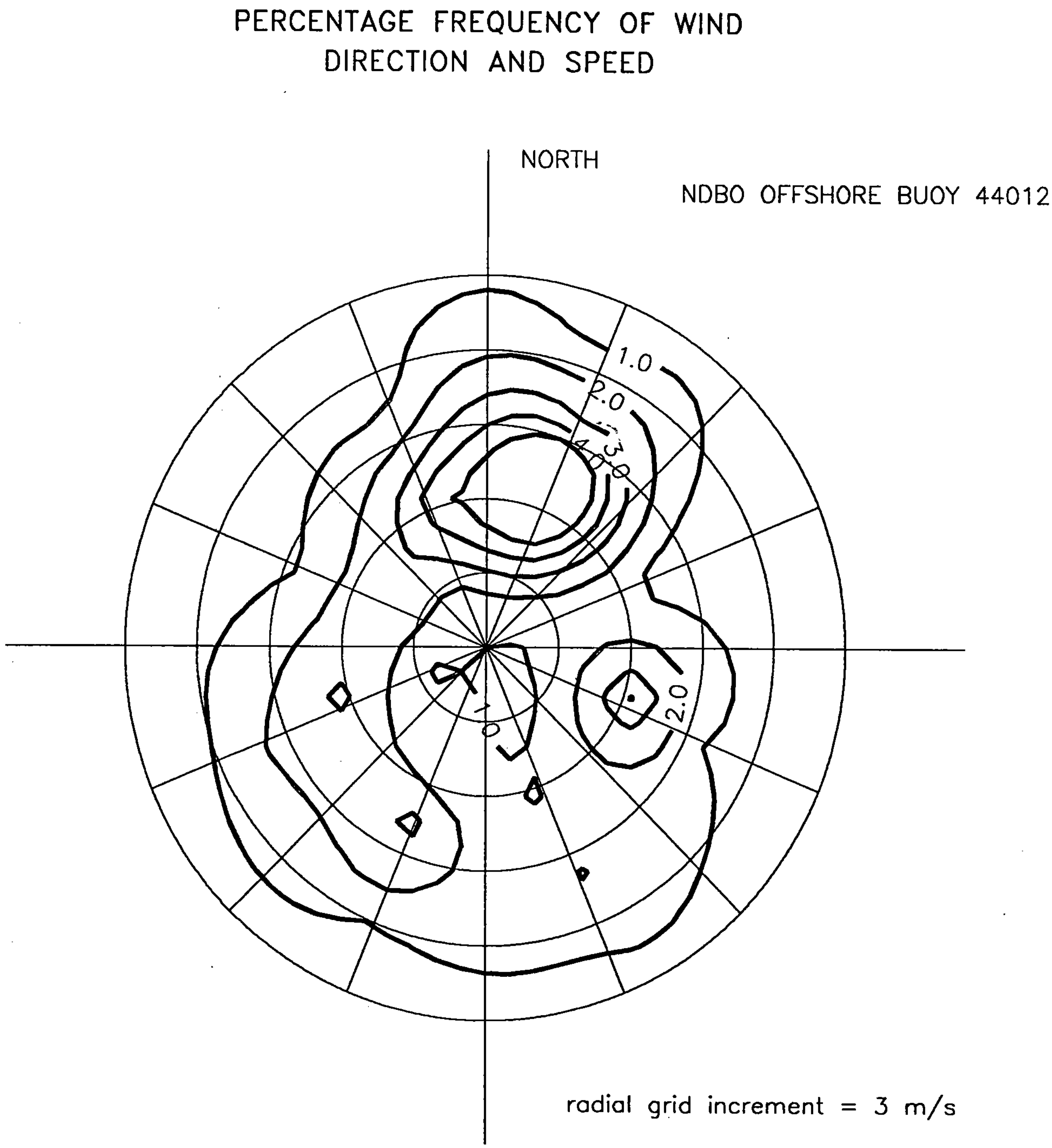

Figure 3.20: Wind rose from Weather Buoy 44012 wind data 26 Mar. - 7 May 1985. Plotted are contours of percentage of frequency of wind direction and speed. Oceanographic convention (wind toward the north is upward).

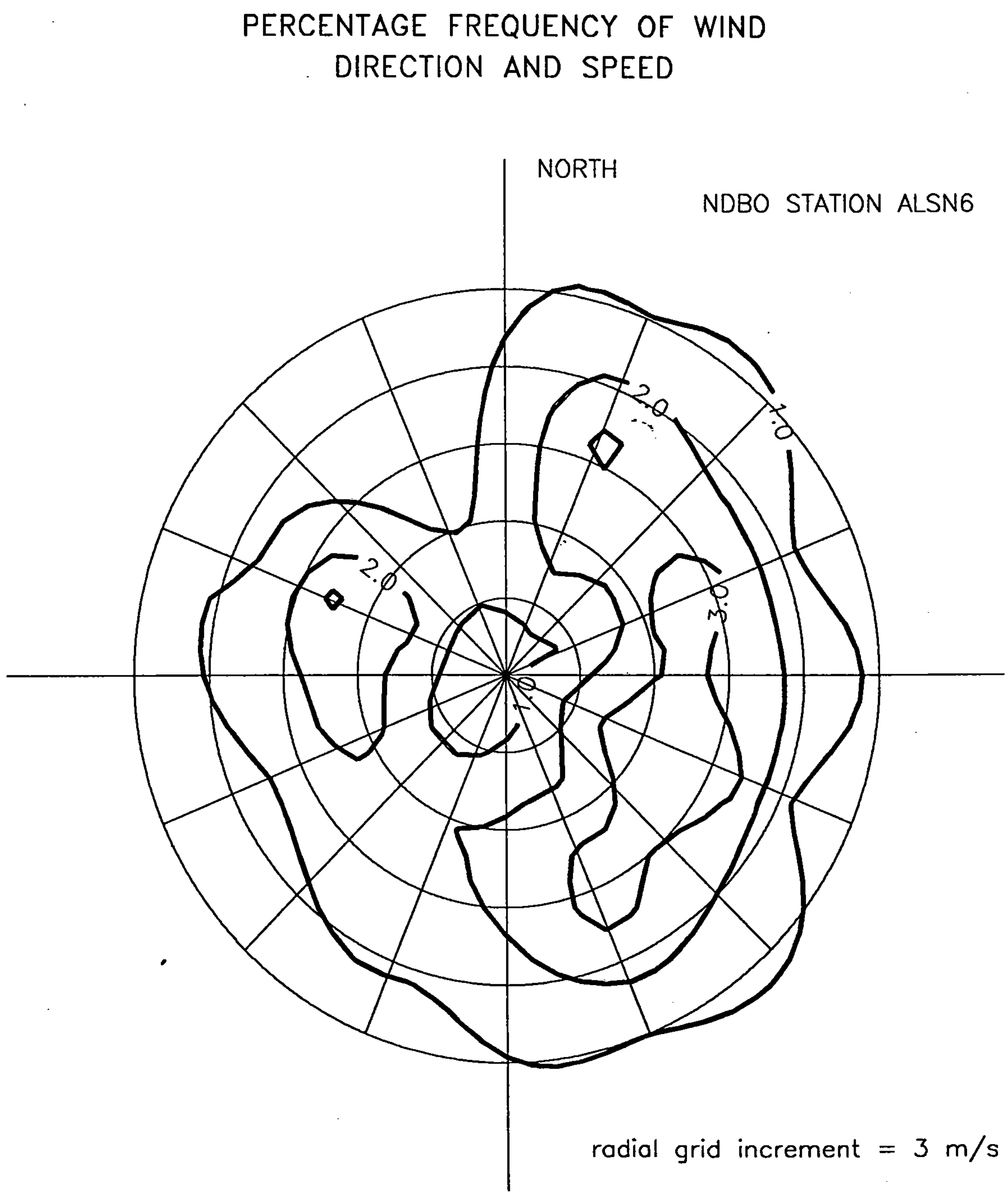

Figure 3.21: Wind rose from Weather Buoy ALSN6 wind data 26 Mar. - 7 May 1985. Plotted are contours of percentage of frequency of wind direction and speed. Oceanographic convention (wind toward the north is upward).

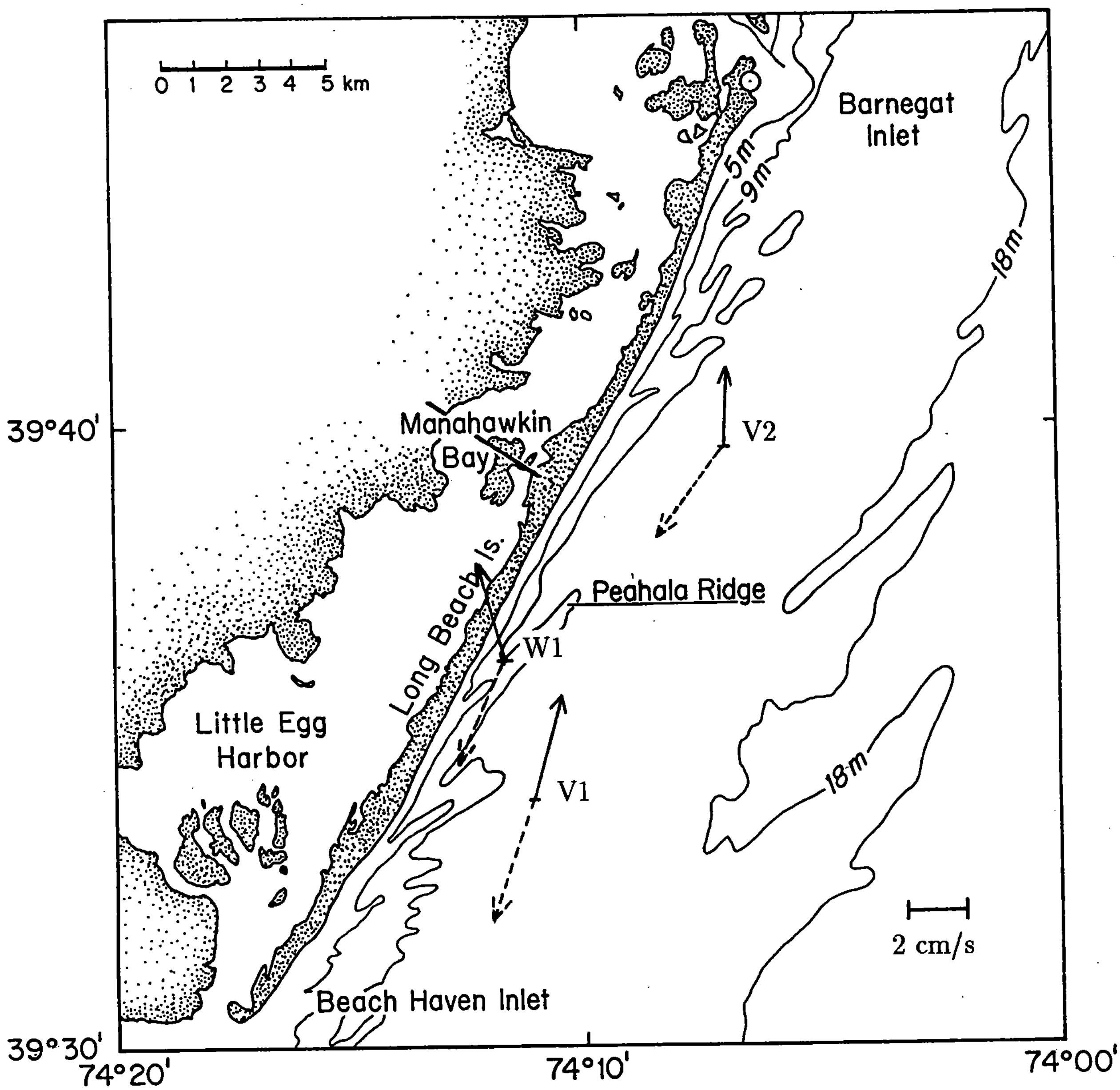

Figure 3.22: Mean up-coast and down-coast velocities.

Table 3-8

Complex correlation between wind and currents. Negative orientation indicates that the current is counterclockwise relative to the wind.

Complex Correlation and Phase between Wind and Currents				
	current meter	instrument depth (m)	correlation	orientation
Wind at	V1: VACM South	11	0.561	-9
Offshore Station	V2: VACM North	11	0.568	-10
Cape May	W1: Wave Gauge	7	0.583	-16
Wind at	V1: VACM South	11	0.630	-61
Sea Man Station	V2: VACM North	11	0.661	-59
Sandy Hook	W1: Wave Gauge	7	0.651	-68

3.2 NEAR-BED VELOCITY PROFILE

Data Reduction

BASS sensors measure the travel time of acoustic pulses along four axes (1 redundant) crossing a 15 cm pathlength measurement volume at high frequency (5 hz). To process these data into velocity and stress measurements, the signal was first zero-shifted to compensate for electronic offsets, using the results of pre-deployment zero flow calibrations, converted to velocities, and then rotated into a horizontal right-hand coordinate system. The two horizontal current vectors were averaged over 10 minute periods. Each BASS tripod contained an array of 4 BASS sensors mounted vertically. If assumptions about neutral stratification and homogeneity hold, the velocity profile is predicted by

$$u = \frac{u_*}{\kappa} \ln z/z_o$$

where u_* is the shear velocity, z_0 the roughness length and κ von Karman's constant (e.g., Clausen, 1956; Gross *et al.,* 1986). Using this equation, u_* and z_0 were estimated in a least squares sense from the velocity profile data. The regression coefficient r^2 is an indicator of the validity of the assumptions.

Because of the incomplete data return from the EMCM tripod A1, it was unreliable for calculating stress estimates.

Stress Estimates

BASS observations were intermittent throughout the experiment depending on the observations of shore side personnel. A continuous time series of currents, stress or any other parameter measured by the BASS tripods cannot be obtained because of the sparseness of the data (see Figure 2-1). However, stress was calculated from the first 10 minutes of all bursts of at least 10 minutes in duration, but only those bursts which were separated from the last by 1 hour or more.

Presented in Figures 3-23 and 3-24 are the estimates of shear velocity u_* and roughness length z_o for bursts where the log profile r^2 was greater than 0.95. 95% confidence limits are shown for u_*. Figures 3-25 through 3-26 show u_* plotted in vector form using the mean flow direction as the direction of stress.

3.3 WAVES

Data Reduction

Two Sea Data 635 Wave Gauges recorded bursts of high frequency horizontal velocity and bottom pressure at stations W1 and W2. Spectra of the frequency content of the pressure and velocity were calculated and peak period and variance determined. Using linear wave theory, sea surface variance was calculated from both the pressure and the velocity and significant wave height from pressure. Finally the co- and quad-spectra of pressure and velocity were calculated and the directional spectrum estimated (e.g., Grosskopf *et al.,* 1983).

Wave Observations

Shown in Figures 3-27 and 3-28 are time series wave statistics for Wave Gauges W1 and W2. W1 burst sampled every 3 hours and W2 every 4 hours. The time series show very good correlation, not surprising considering there proximity of about a kilometer. Wave conditions varied from calm to 2 m significant wave height with peak directions from about 45° to 170° (the figures show direction toward which the waves are traveling). W2 was in deeper water at 15 m and clearly shows loss of signal in the velocity variance statistic due to wave attenuation with depth. Only during periods of very large waves is some of the sea surface variance recovered. This makes directional information difficult to recover. Period estimates are noisy due to sensitivity to system noise but show a trend toward increased wave period during and after large wave events. When compared to time series of wind (Figure 3-29), the time series show major wave events closely correlated to wind from the NE except for one event of strong winds (the strongest of the study) from the south around April 6th. Wave direction changes also tends to correlate with wind direction reversals.

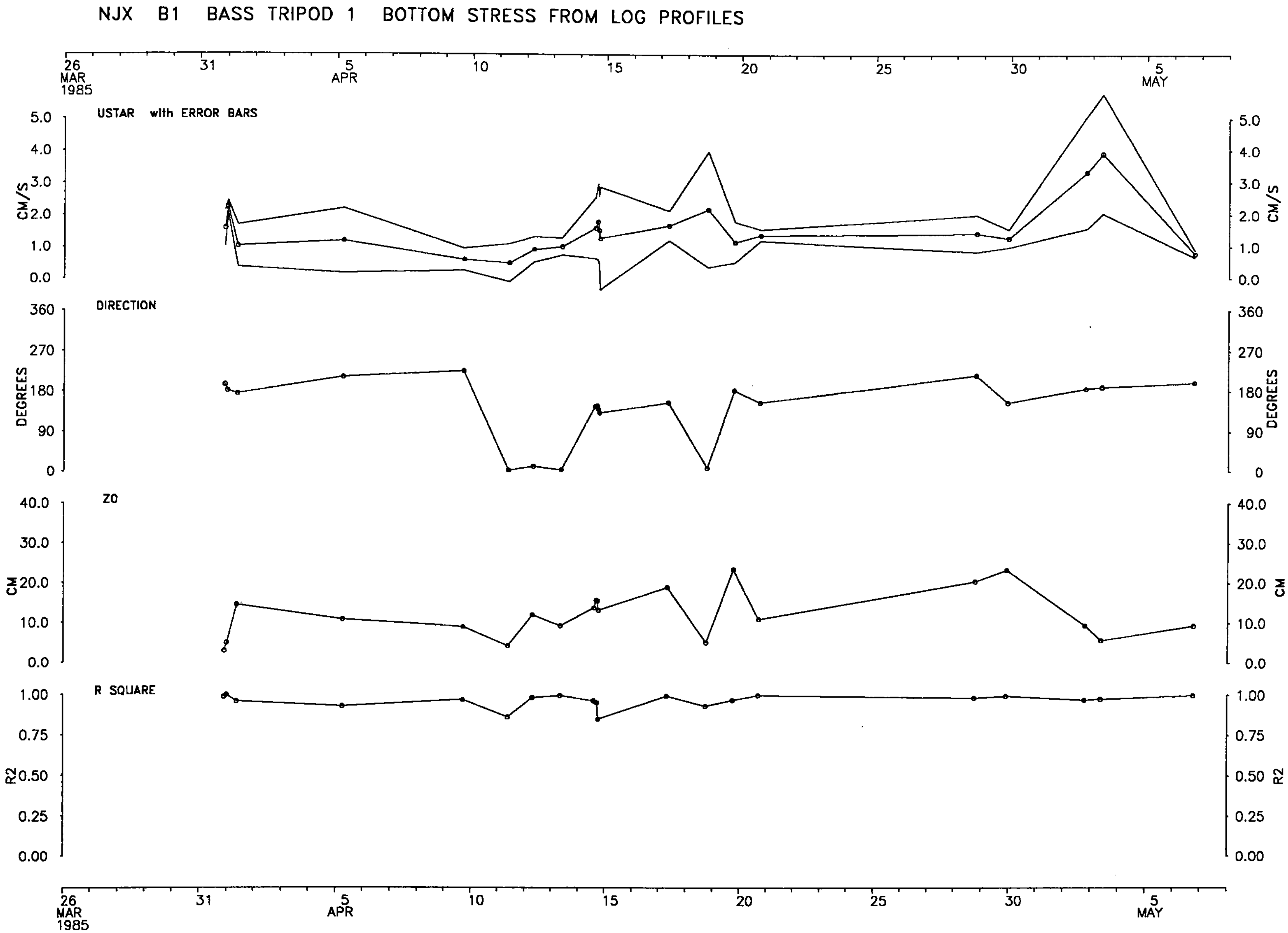

Figure 3.23: Least squares estimates of shear velocity u_* (with 95% confidence limits) and roughness length z_0 for BASS tripod B1 calculated from log profiles. Only bursts with r^2 greater than 0.95 are shown. Also shown are the mean current direction and the regression coefficient r^2.

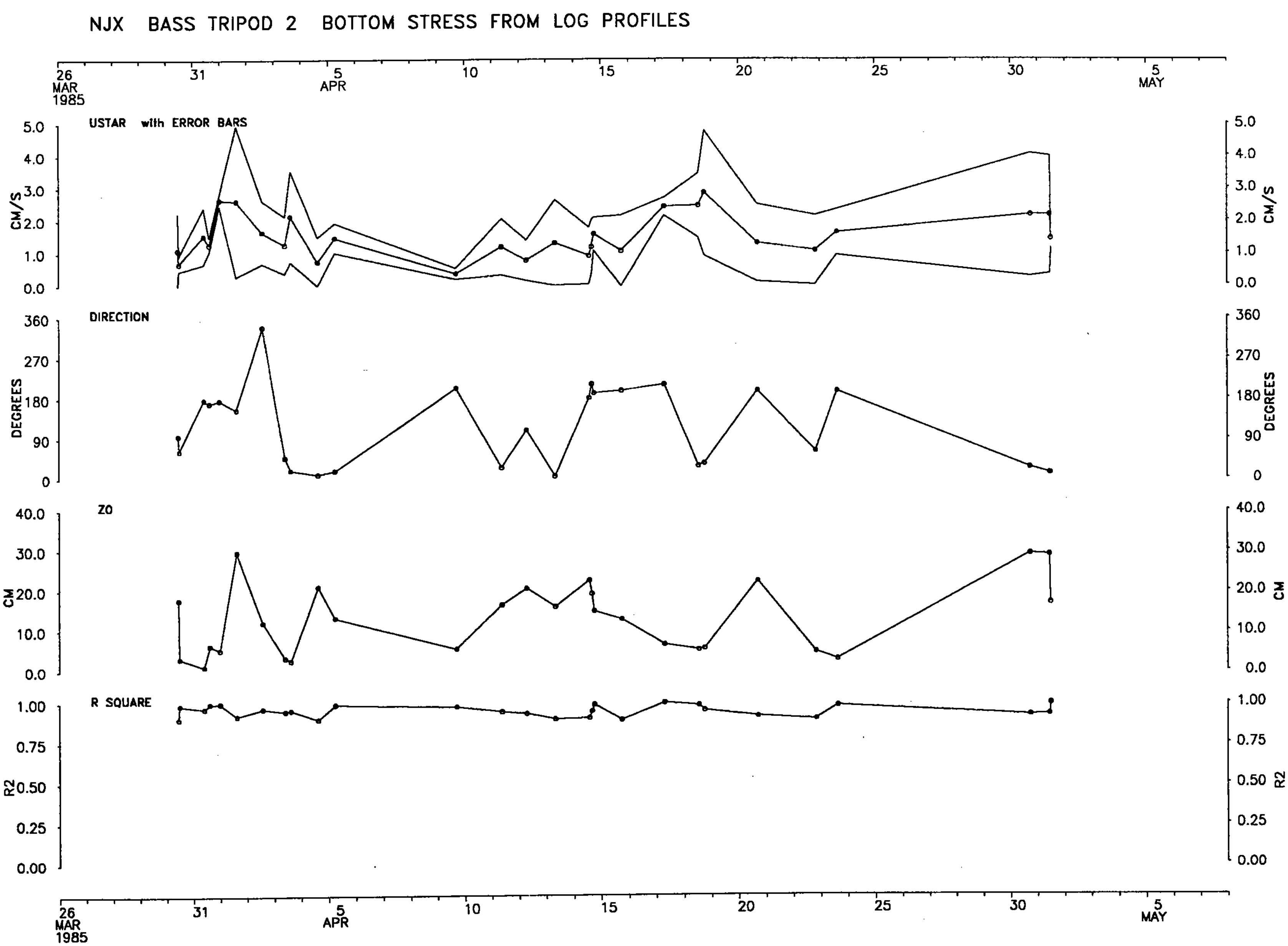

Figure 3.24: Least squares estimates of shear velocity u_* (with 95% confidence limits) and roughness length z_o for BASS tripod B2 calculated from log profiles. Only bursts with r^2 greater than 0.95 are shown. Also shown are the mean current direction and the regression coefficient r^2.

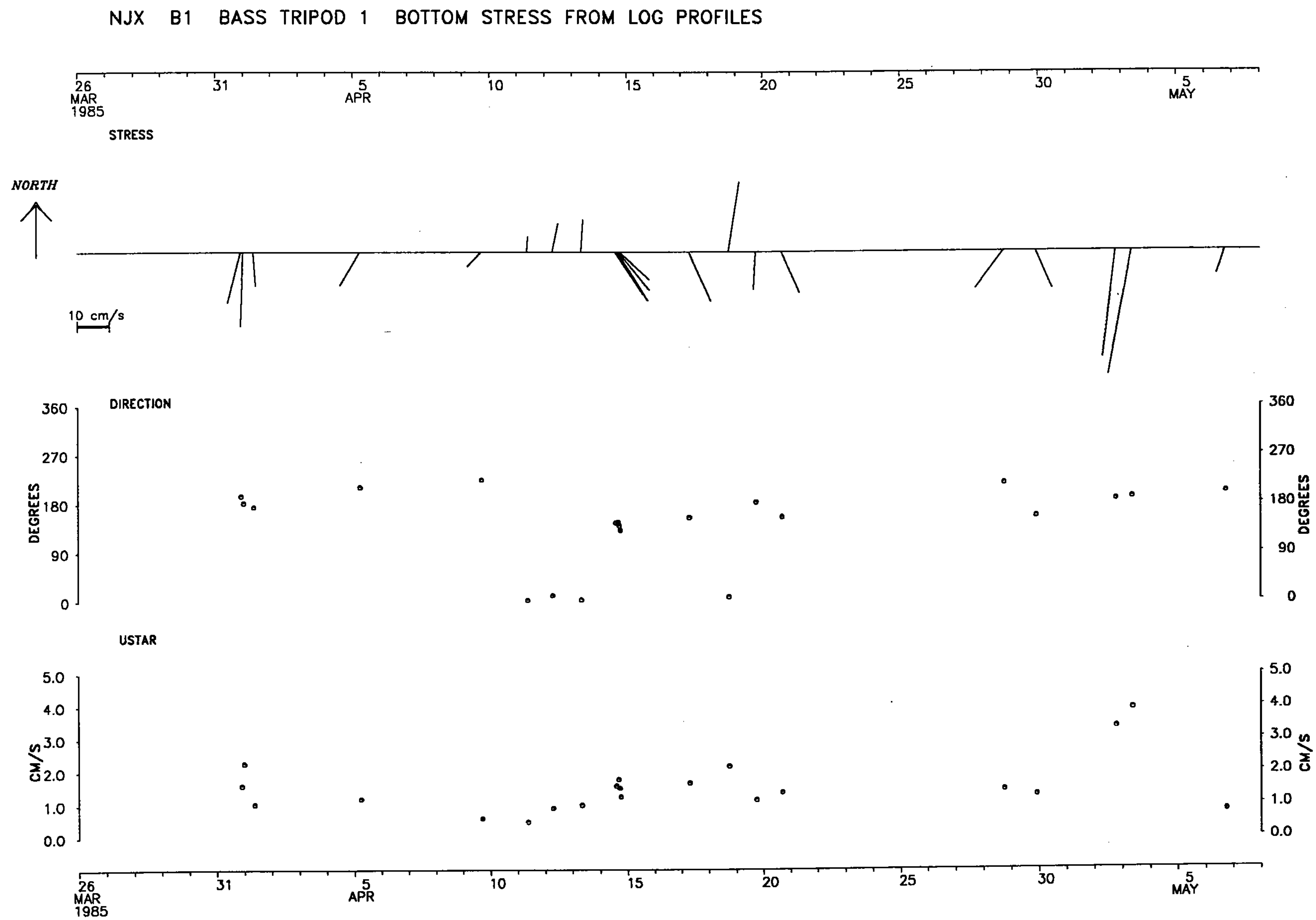

Figure 3.25: Vector plots of the least squares estimates of shear velocity u* in the direction of the mean current for BASS tripod B1. Only bursts with r^2 greater than 0.95 are shown.

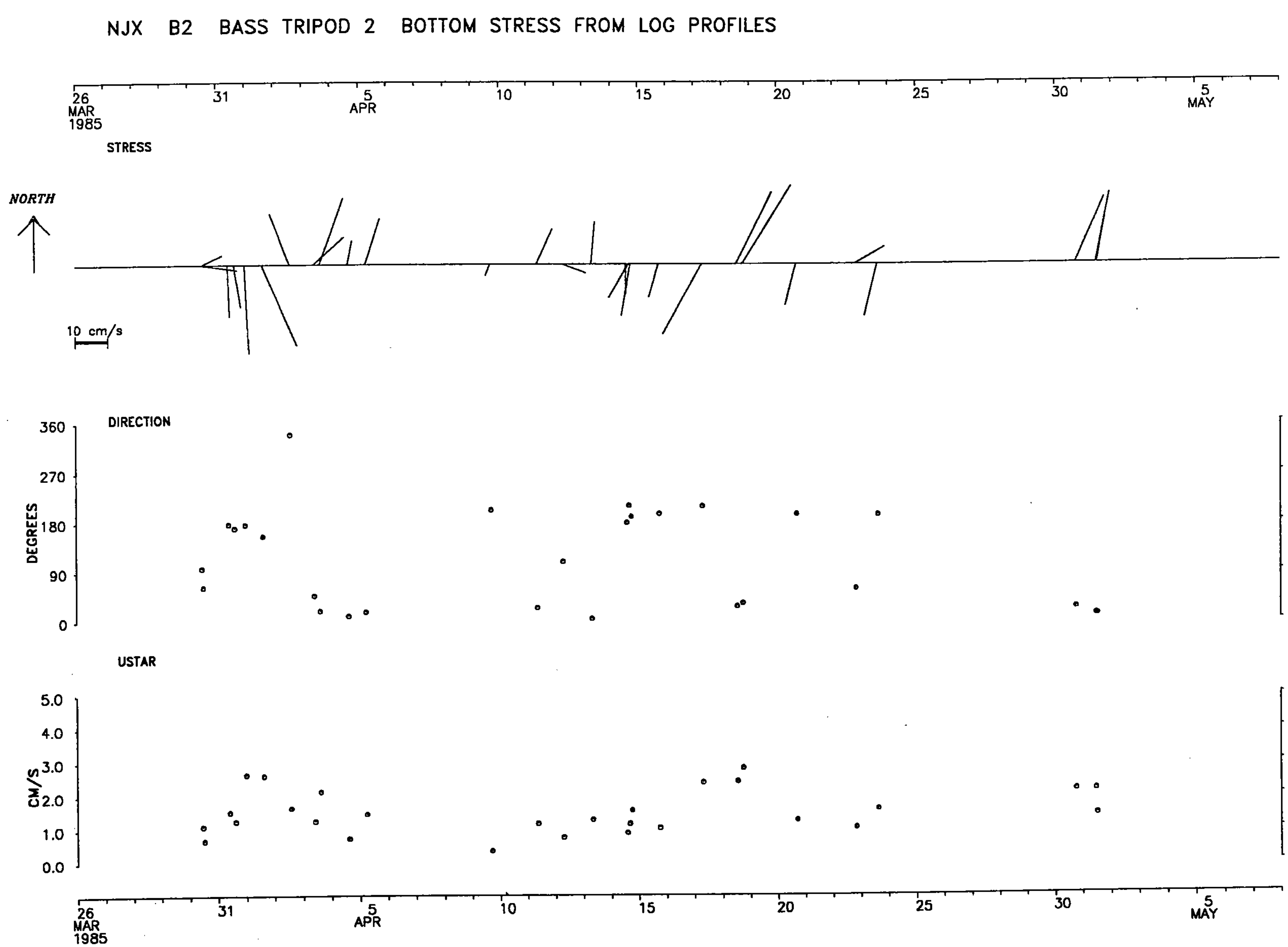

Figure 3.26: Vector plots of the least squares estimates of shear velocity u* in the direction of the mean current for BASS tripod B2. Only bursts with r^2 greater than 0.95 are shown.

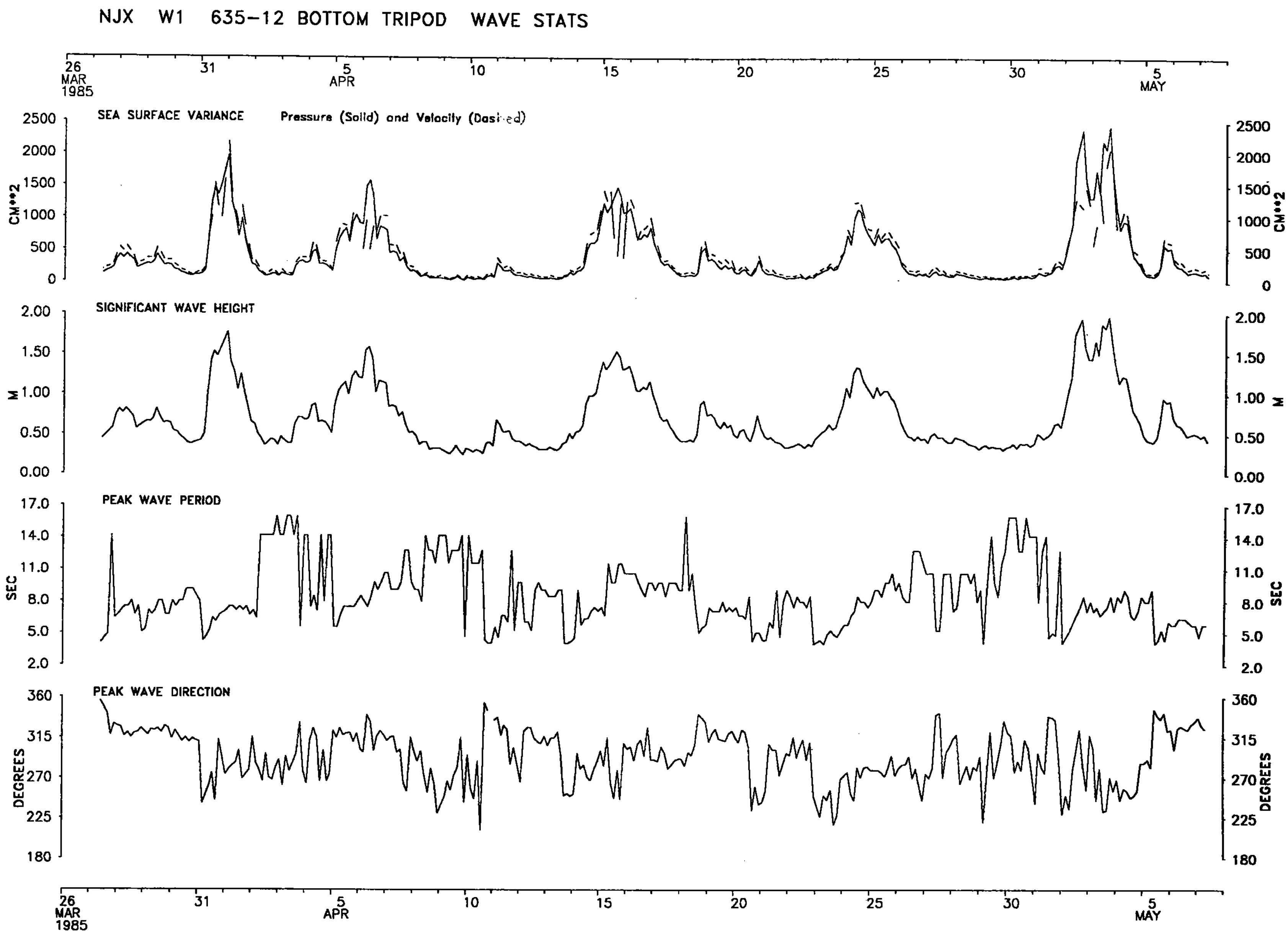

Figure 3.27: Wave statistics from burst measurements of velocity and bottom pressure every 3 hours for Wave Gauge W1 at 7 m depth. Peak wave direction shows direction of wave travel.

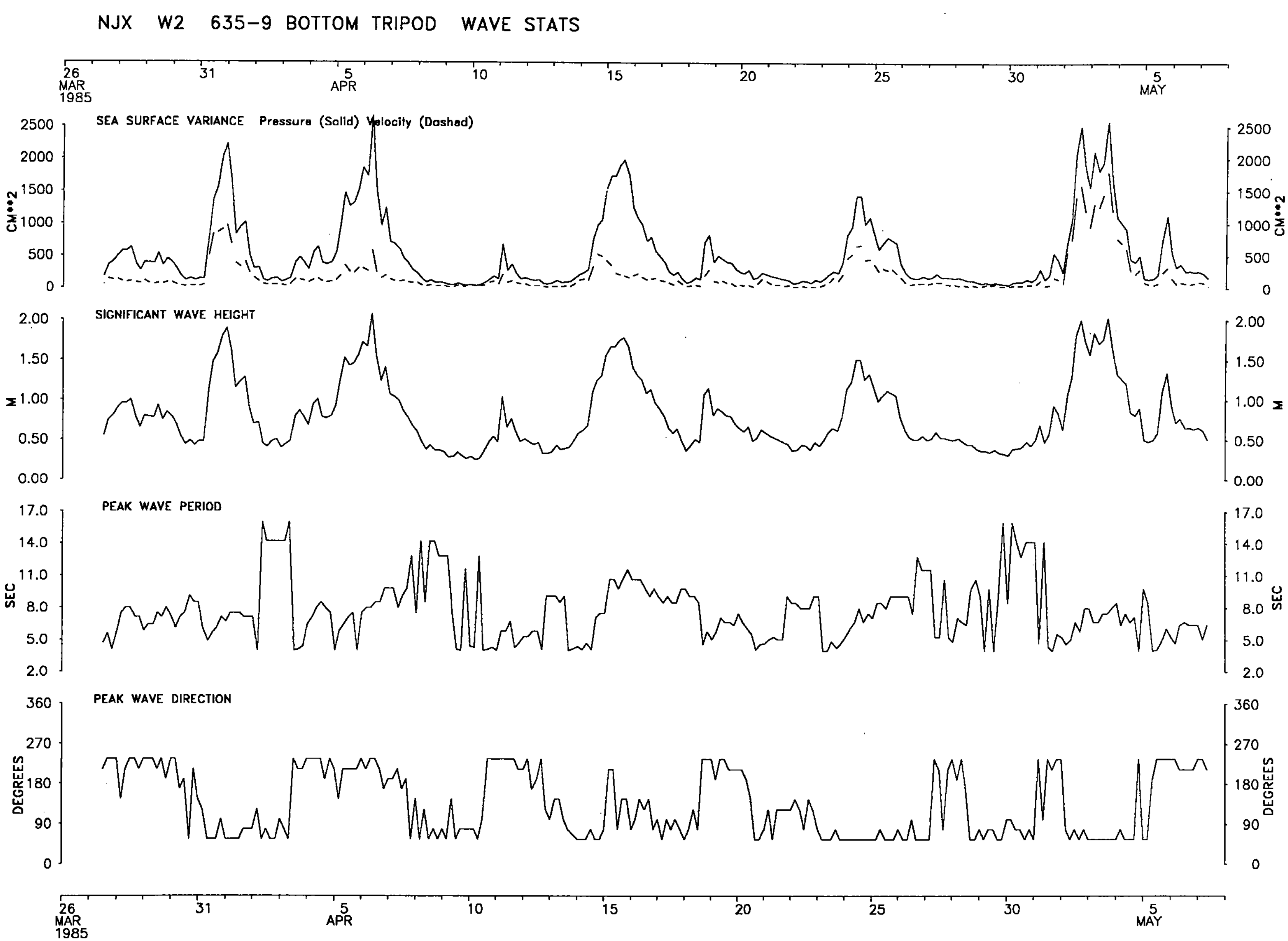

Figure 3.28: Wave statistics from burst measurements of velocity and bottom pressure every 4 hours for Wave Gauge W2 at 15 m depth. Peak wave direction shows direction of wave travel. Estimates of peak wave direction are degraded due to attenuation of velocity with depth.

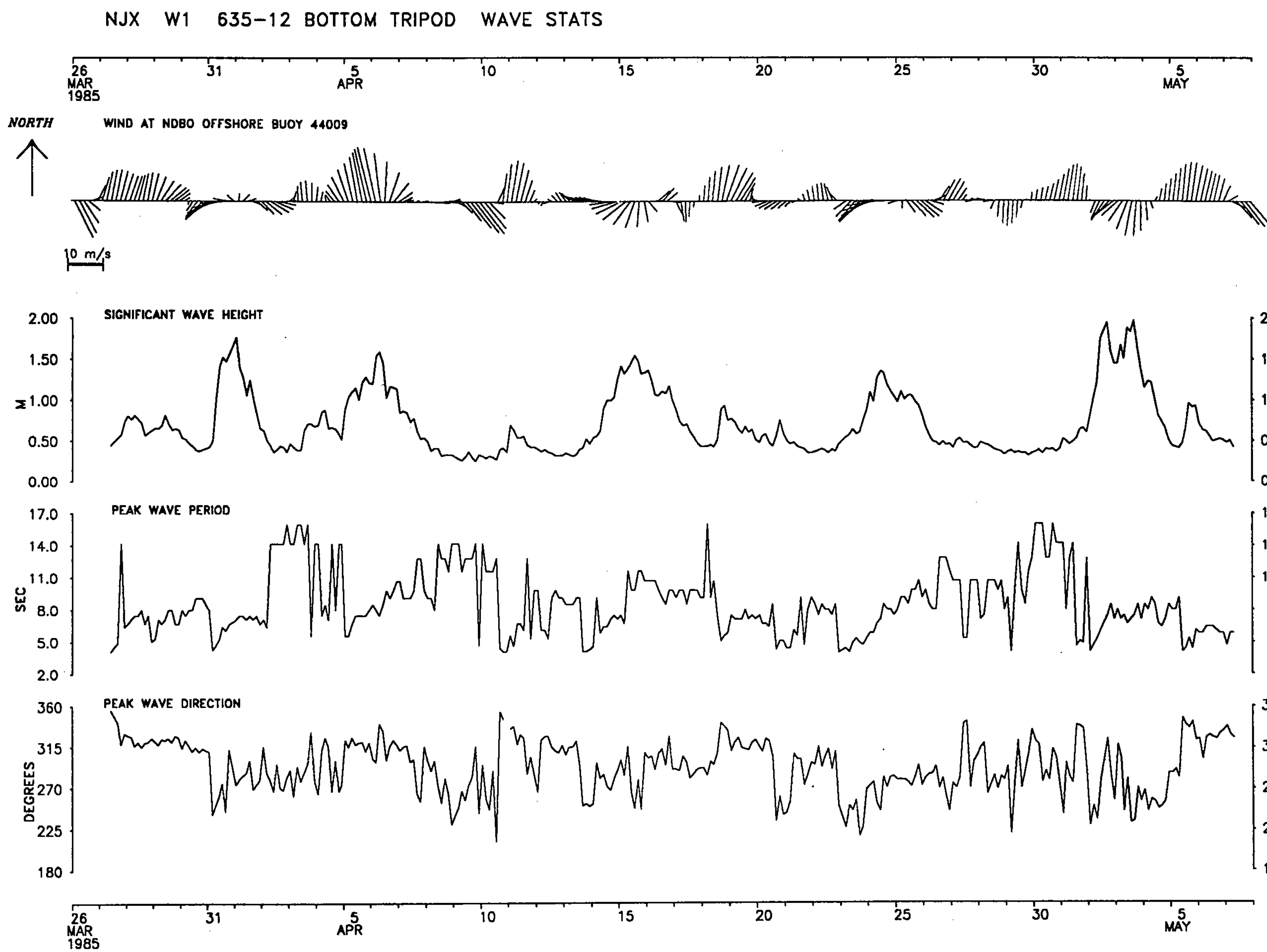

Figure 3.29: Wind at NDBO offshore buoy 44009 and wave statistics from burst measurements velocity and bottom pressure every 3 hours for Wave Gauge W1 at 7 m depth. Direction shows direction of wave travel.

3.4 BOTTOM PRESSURE

Two working TDRs (T2 and T3) and the Wave Gauges at stations W1 and W2 recorded average bottom pressure at 15 min, 3 hour and 4 hour intervals respectively. These time series are shown in Figures 3-30 through 3-33. Data from the TDRs were averaged to hourly intervals. Pressure has been converted to pressure head or depth for consistency with tide measurements. They are dominated by the semi-diurnal tide and show a fortnightly and monthly modulation. Also shown in Figures 3-30 and 3-31 are the temperature observations for T2 and T3. The BASS tripods were also instrumented with bottom pressure sensors, but because the time series are discontinuous the data have not been presented. Shown in Figures 3-34 and 3-35 are the low-pass time series of temperature and pressure with the barometric pressure (from the Sandy Hook Weather buoy) removed.

4. CONCLUSIONS

The measurements made during the present study are unique in their spatial coverage and span of kinematic and dynamic quantities observed or calculated. These observations have contributed significantly to the database for modeling of linear, shore-attached sand ridges.

A quick observation of the data show some interesting features that will require explanation by any model of the maintenance of these features:

- Mean flows are dominated by wind forcing rather than tidal forcing.
- The low tidal currents in the area show considerable spatial variability in orientation of the major axis of the M_2 tidal flow. Near the sand ridge, the major axis is directed onshore; to the north, the tidal axis is inclined to the coast approximately 30°.
- Wind-driven mean flows are strongly linear, with major axes oriented nearly 30° to the shore over the ridge, and alongshore at both of the offshore stations (V1 and V2). This veering in the mean wind-driven flow may be contribute to the maintenance of the sand ridge and its movement northward.
- The magnitude of bottom stress measured within the trough of Peahala Ridge and on the crest of the Ridge were comparable in magnitude, generally within the 95% confidence limits of the stress estimates. Directions of bottom stress varied between sites, at times being 180° out of phase, and nearly always at an angle to each other.
- The data could not resolve a pressure gradient alongshore due to failure of some of the pressure loggers, so the role of the alongshore pressure gradient in setting up maintaining flows for the features cannot be determined.
- High bottom stress was experienced during all periods when waves exceeded 1 m in amplitude, suggesting that the wave/current interactions (e.g., Grant and Madsen, 1979) may be important in modeling these features.

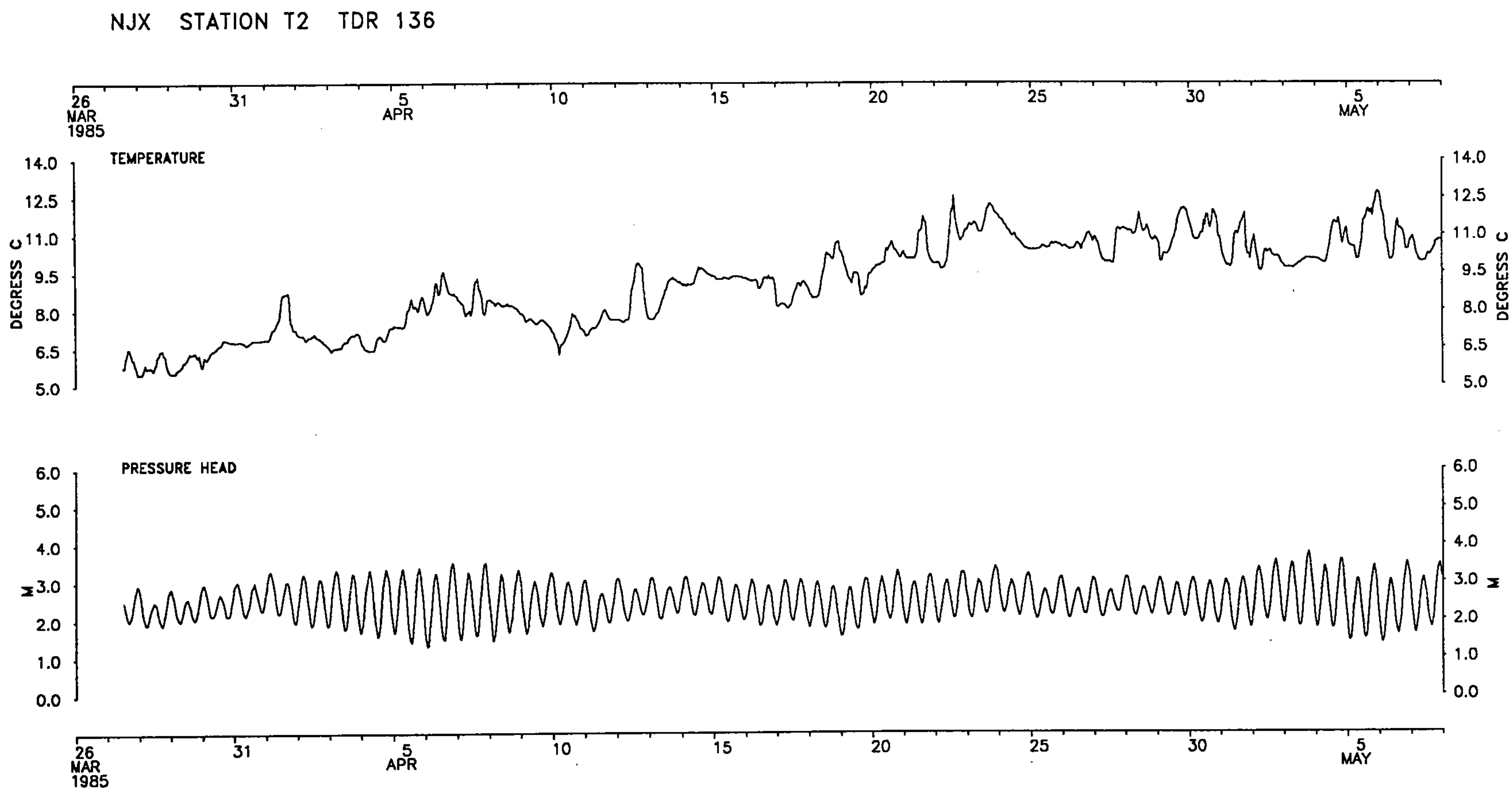

Figure 3.30: Hourly time series of pressure and temperature for station T2. Pressure has been converted to pressure head or depth.

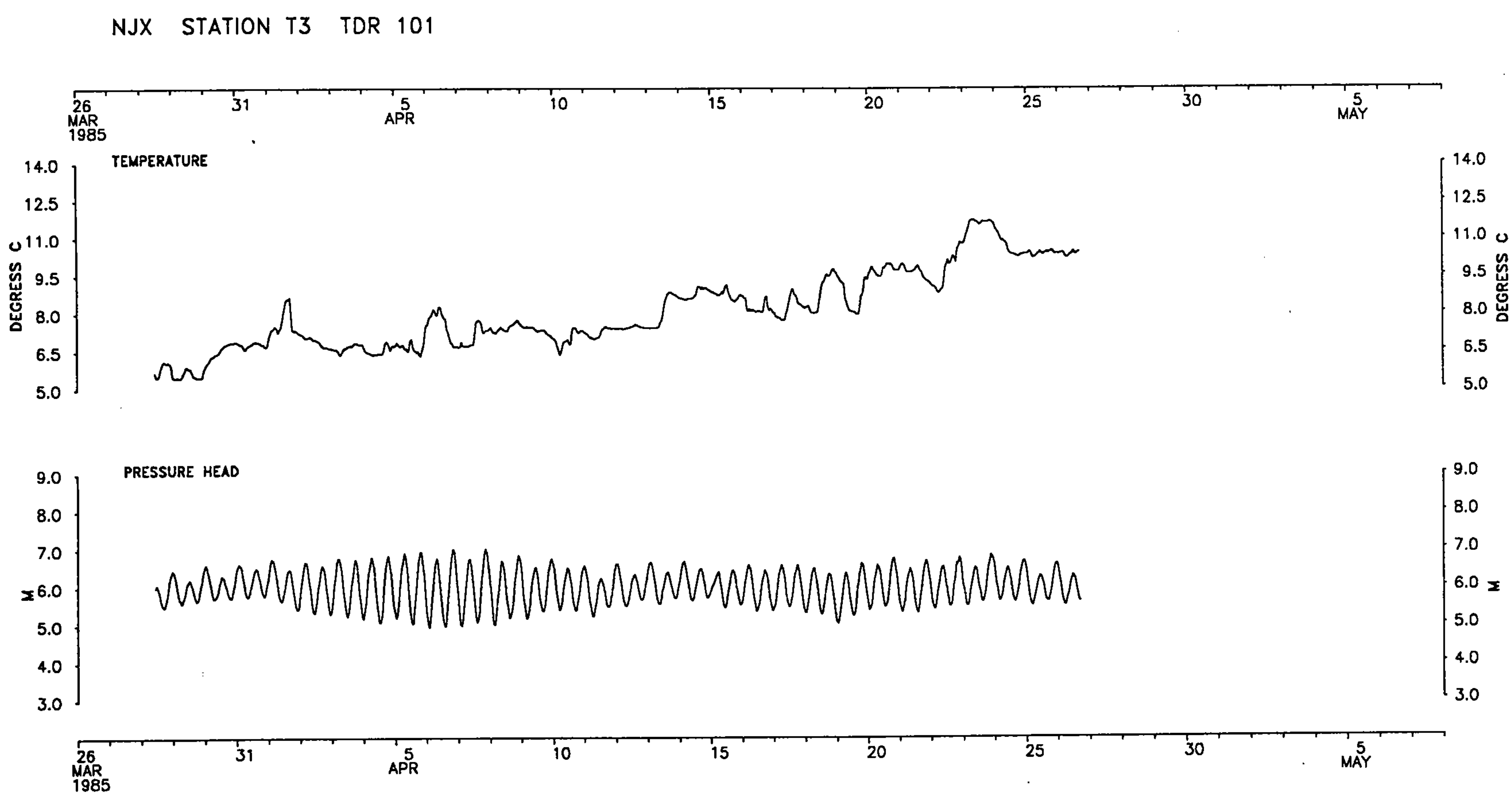

Figure 3.31: Hourly time series of pressure and temperature for station T3. Pressure has been converted to pressure head or depth.

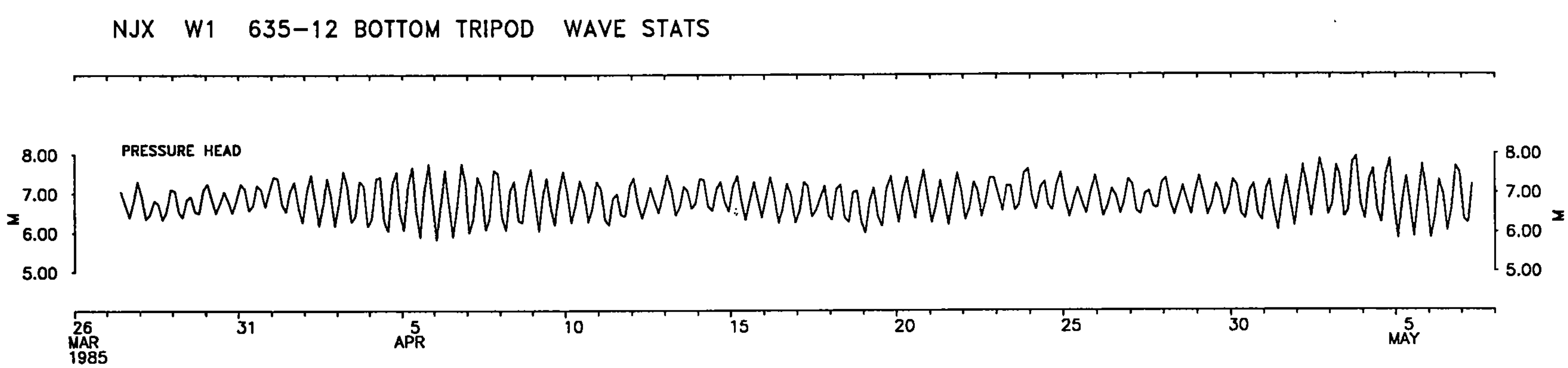

Figure 3.32: Time series of 3 hour averages of pressure for station W1. Pressure has been converted to pressure head or depth.

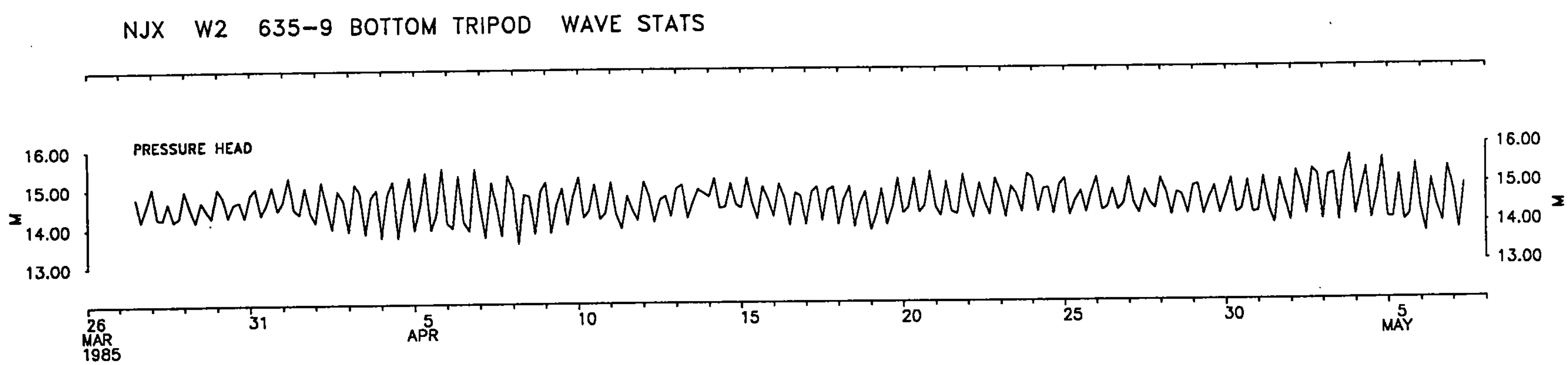

Figure 3.33: Time series of 4 hour averages of pressure for station W2. Pressure has been converted to pressure head or depth.

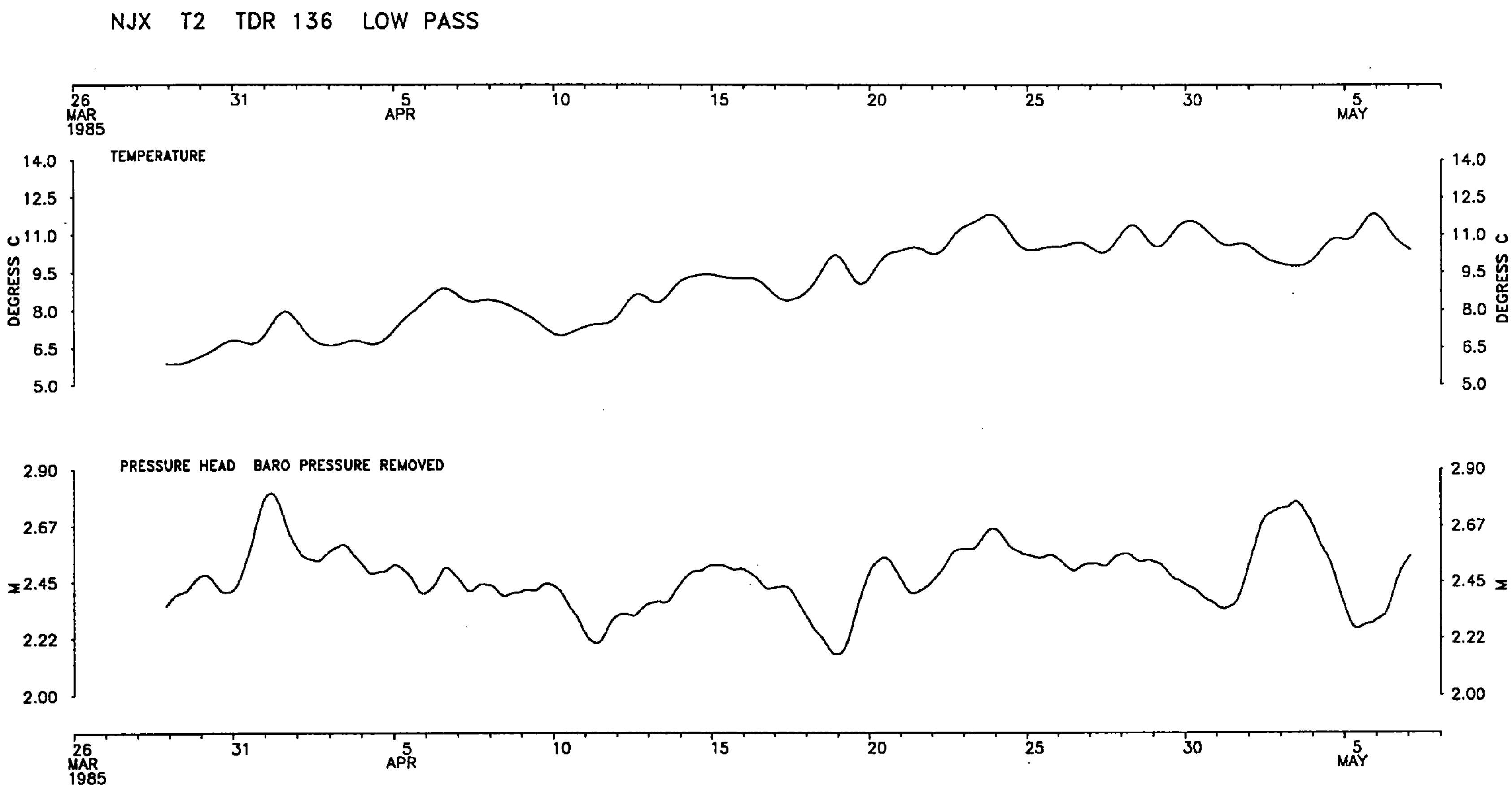

Figure 3.34: Low-pass time series of pressure and temperature for station T2. Pressure has been converted to pressure head or depth and barometric pressure has been removed.

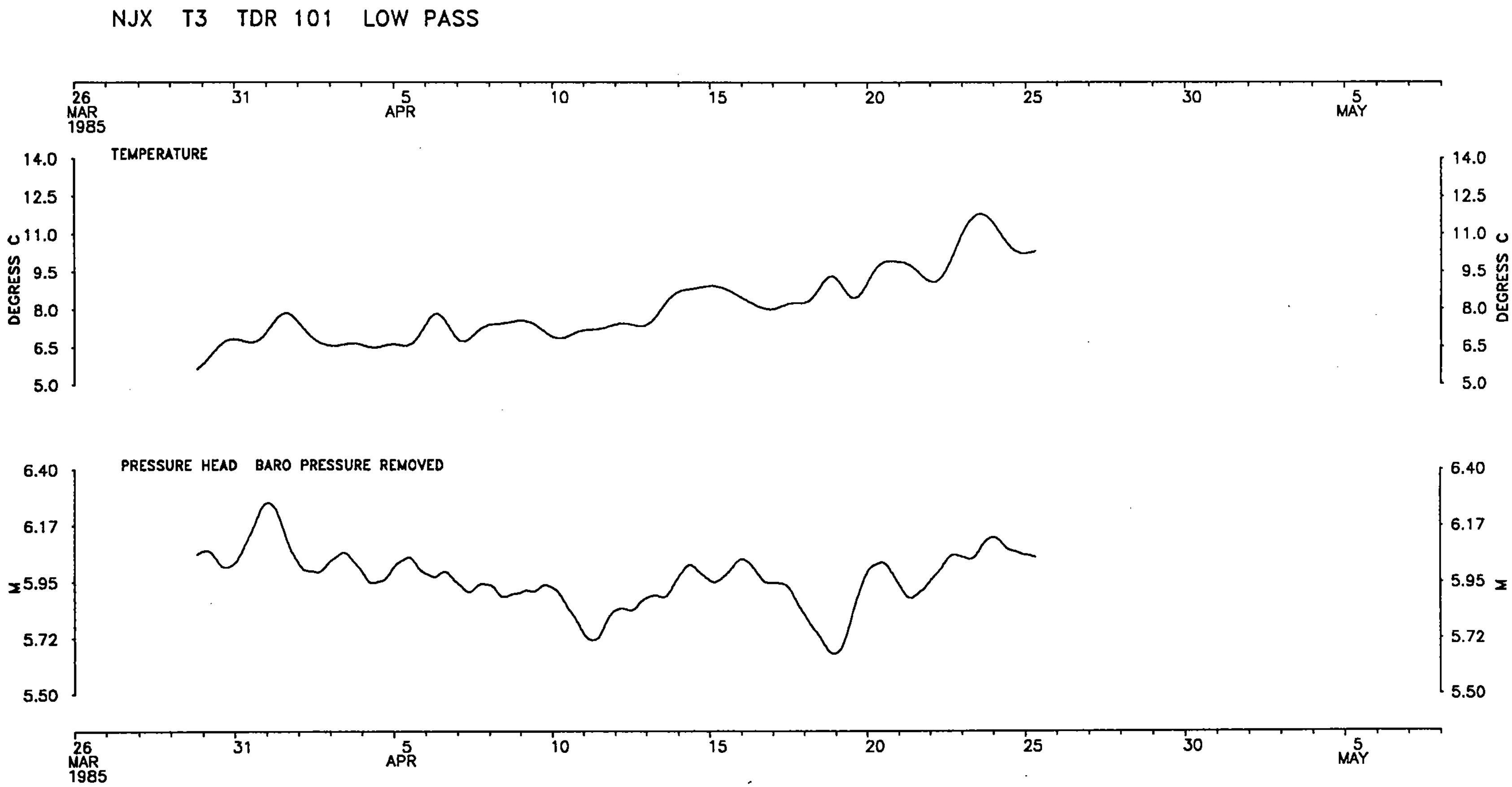

Figure 3.35: Low-pass time series of pressure and temperature for station T3. Pressure has been converted to pressure head or depth and barometric pressure has been removed.

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16. Abstract (Limit: 200 words)

This report describes and presents the hydrodynamic measurements made during the Atlantic Shelf Sand Ridge Study at and near Peahala Ridge, offshore of Long Beach Island, New Jersey, in Spring 1985. The intent of this phase of the study was to examine the physical oceanographic and fluid mechanical processes in the vicinity of Peahala Ridge, one of the large shore-oblique sand ridges common in the area, and from this to identify those processes responsible for sand transport near the ridge with particular reference to its generation, maintenance and migration. The field measurement program was carried out from March to May 1985 by scientists and staff of the Woods Hole Oceanographic Institution. It included measurements of currents, temperature, waves, pressure and near-bed velocity profiles. This phase was part of a larger oil industry study that included extensive geological and geophysical measurements of Peahala Ridge and other ridge-and-swale areas of the mid-Atlantic continental shelf.

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3. New Jersey
4. sand ridges

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